

A GUIDE FOR REFURBISHING ABANDONED SOLAR POOL SYSTEMS

**Prepared for the Department of Defense
Headquarters United States Marine Corps.**

**Renewable Energy Office
Sandia National Laboratories**

Earl Rush
Solar Thermal Test Department
505-845-3331, MS1127
eerush@sandia.gov

Dave Menicucci
Renewable Energy Office
505-844-3077, MS 0704
dfmenic@sandia.gov

CONTENTS

Foreword.....	4
Introduction	5
Instructions for Using this Manual.....	6
Step 1: Inspect the System	8
Checklist	8
Step 2: Testing the System	20
Step 3: Analyzing the System.....	23
Step 4: Repair the System	25
Develop a Statement of Work.....	25
Hire a Contractor.....	27
Monitoring the System	27
Maintenance Agreement	27
Training	32
O&M Manual	32
Conclusions	33
Acronyms and Definitions.....	34
Reference Documents	36
Appendix A: Specifications for the Solar Collectors on the Area 14 Training Tank at Mcb/Camp Pendleton, Ca	A-1
Appendix B: Executive Order 13123 Greening the Government Through Efficient Energy Management.....	B-1
Appendix C: Corrosion.....	C-1
Appendix D: Two Case Studies	D-1
Appendix E: Economic Analysis Worksheet.....	E-1
Appendix F: LCCID.....	F-1
Appendix G: Manufacturers List of BTU Meters (8/2000).....	G-1
Appendix H: Example of O&M Manual.....	H-1

FOREWORD

Although the exact date is not readily known, the solar pool heating systems at MCB Camp Pendleton were initially installed in the early 1980s. It is believed by some that were on the base staff soon after this installation work that that these systems were never properly commissioned. Major failures include pumps installed “backwards” to correct flow, leaking collectors and couplings, and non-functioning control systems. At least once, at an unknown number of systems, the complete array of solar collectors was replaced. In brief, until 1997, the solar panel heating systems were a constant source of maintenance demands. It seems quite likely that some or all of the various systems may never have been fully functional.

In 1997, Sandia National Laboratories out of Albuquerque, NM, was requested by Headquarters, United States Marine Corps, to review the status of the systems and forward its observations and recommendations to Headquarters Marine Corps. Initial inspections strongly suggested that these systems could be made functional and very effective energy saving devices if refurbishment could be accomplished with the limited funds available. Sandia was subsequently asked to oversee the project and funds were forwarded to do so.

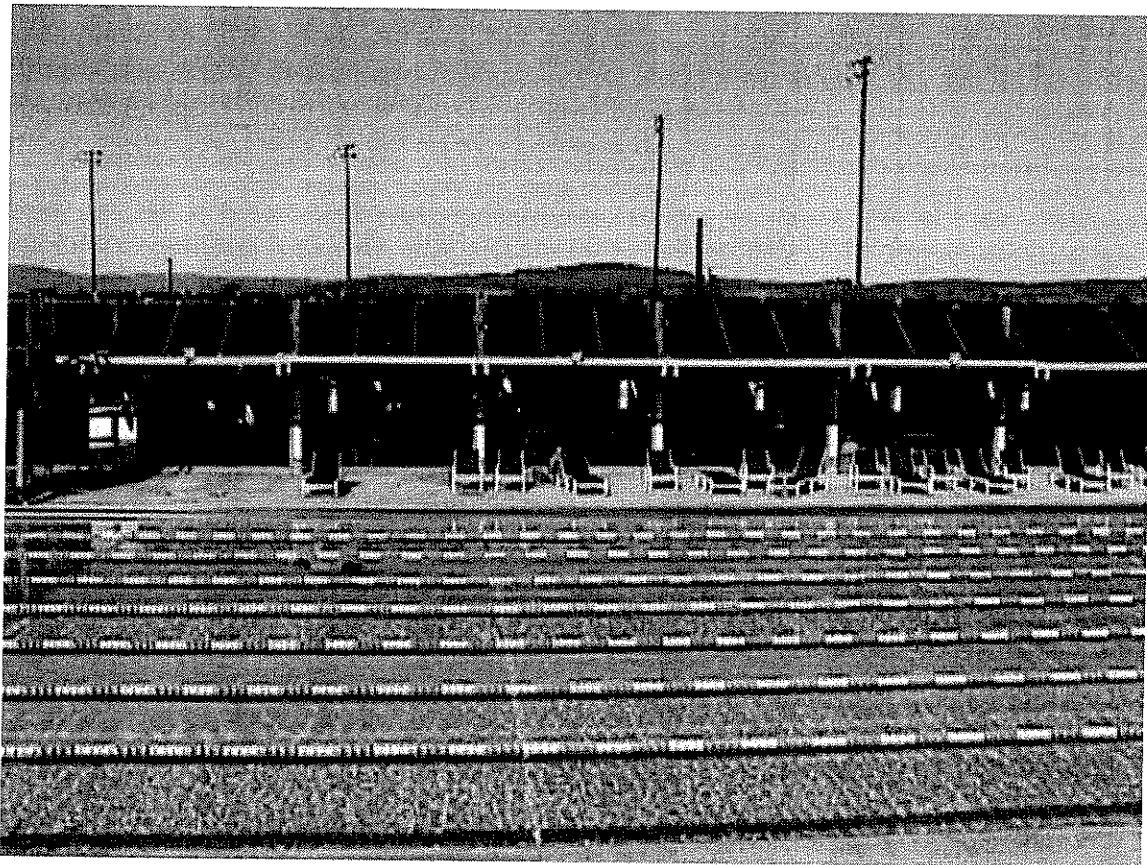
A Request for Quote (RFQ) was set forth and a local, long-established solar contracting and service company—Mike Walsh Enterprises—was eventually awarded a contract. Refurbishment work was initiated in February of 1998 and was substantially completed in July of that year. Work included resurfacing the existing solar collectors, installation of new, properly sized circulator pumps, repair and/or replacement of 6” butterfly valves and actuators, and the fabrication and installation of new control packages. Additionally, BTU meters, an integral part of energy monitoring systems (EMS), were placed at each functioning system to document energy production. The systems are now on line.

As part of the effort, HQ/USMC asked Sandia to develop a guide for refurbishing solar pool systems so that other solar pool systems can be refurbished using facilities expertise. This manual is intended to meet this objective.

INTRODUCTION

When solar energy was very popular in the early 1980s, many government institutions rushed to install solar pool systems for heating water and swimming pools. Unfortunately, following installation, regular maintenance was frequently neglected. Consequently, minor problems that caused system malfunctions led many organizations to abandon on-site solar pool systems. In many cases, the systems can be cost-effectively brought back into operation. In some cases, however, the condition of the system is such that the system cannot or should not be refurbished. In this case, it should be removed. However, solar panel system problems are often easy to identify and inexpensive to repair.

This manual is intended as a guide for field engineers and technicians who are contemplating the refurbishment of an existing, non-operational solar pool system.



INSTRUCTIONS FOR USING THIS MANUAL

The instructions in this manual apply to government or military teams refurbishing abandoned solar pool systems.

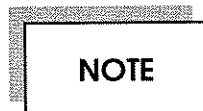
This manual assumes that the people using this manual have a solid electromechanical background and are accustomed to working with fluid systems, especially hot water systems.

It is important to understand that this manual does not teach these fundamentals, but rather will assist someone with a basic knowledge of solar pool systems to determine if their solar system can be refurbished and if refurbishment is worth the cost.

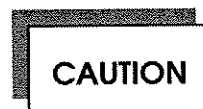
This manual will describe and explain a simple, four-step process to evaluate and refurbish an abandoned solar panel system. The Summary Table below gives an overview of the four steps: 1) Inspect, 2) Test, 3) Analyze, and 4) Repair.

By applying this systematic approach, the owner of an abandoned solar panel system can determine if refurbishing the system makes good sense. Refurbishment projects can be very cost-effective, some resulting in paybacks as short as six months. There are some pitfalls, but with proper maintenance, hot water from refurbished solar pool systems can compete with natural gas.

Legend



Indicates operating procedures, conditions, etc., that are essential to highlight.



Indicates operating procedures, practices, etc., that, if not strictly observed, will result in damage to or destruction of equipment.



Indicates operating procedures, practices, etc., that, if not strictly observed, will result in personal injury or loss of life.

Summary of Four-Step Process		
Step	Action	Summary
1	Inspect the System	Visually inspect the system. Look for leaks or corrosion. Assess the overall soundness of the system. Review the history of the system. This helps to identify what to test, or whether to proceed (the evaluator may stop at this point).
2	Test the System	Fill the system with water and pressurize it. Check the system for leaks. Check operation of all pumps and controls. Determine what control components are needed to be repaired/replaced.
3	Analyze the System	<p>Perform an economic analysis to determine the cost to repair the problems found in Steps 1 and 2.</p> <p>Compare the repair costs to the potential energy savings from operating the system.</p> <p>Determine if the system is worth fixing based on owner's criteria. Draft a statement of work (SOW).</p>
4	Repair the System	<p>Assemble a trained in-house team, or hire a contractor to complete the refurbishment.</p> <p>Install an appropriate BTU meter to verify performance.</p>

STEP 1: INSPECT THE SYSTEM

Step 1 is simply a visual inspection. Minor problems, such as leaks or corrosion, are often visible to a trained eye. Here, the investigative team assesses the overall soundness of the system and reviews its history.

CHECKLIST

1. Look at the major parts (collectors, piping, pumps, controls, mounting structure)
 - Are all the parts there? Abandoned systems are occasionally stripped for parts or partially dismantled during building renovations (see Figure 1). If the balance of the plant is intact (see Figure 2), refurbishment is more likely to be cost-effective.

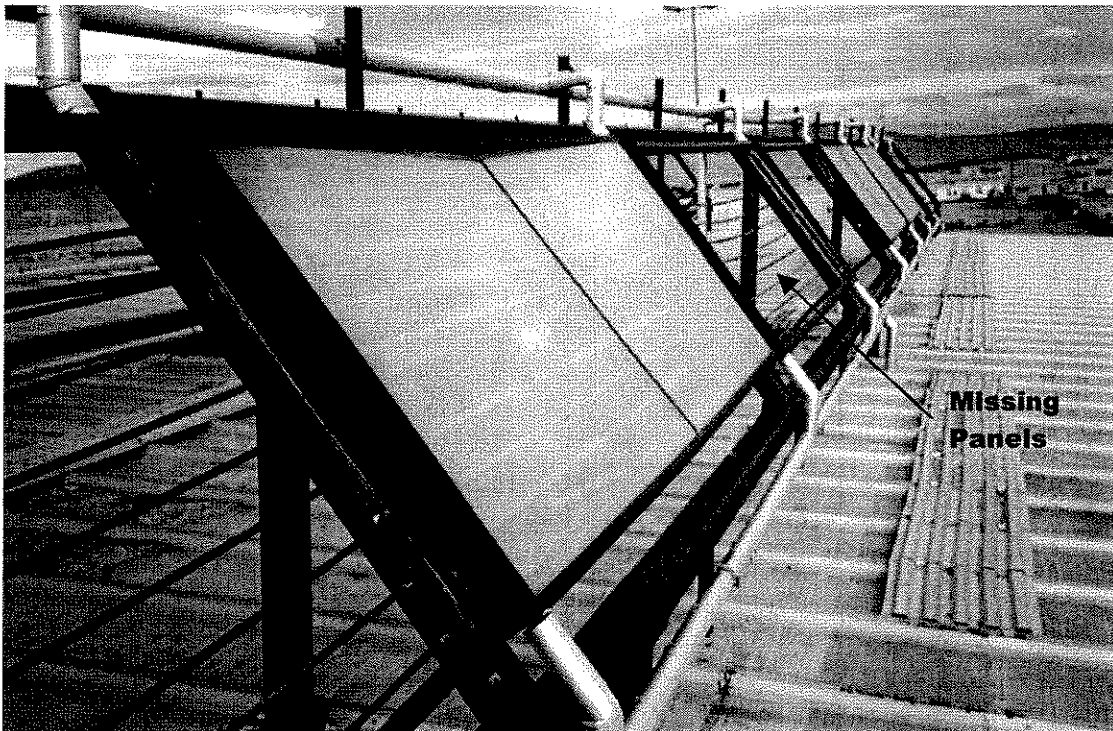


Figure 1. Example of collector field in poor condition.



Figure 2. Example of collector field in good condition.

- What is the condition of the collector? Is there any indication of leaks (see Figure 3)? The collectors are the major cost item. Are they serviceable? Do they work? Could they be repaired? Figure 5 shows collectors that were damaged, but salvageable. Initial inspection of the collectors can sometimes tell you immediately whether or not you have a system worth refurbishing. Figure 4 shows a solar array too damaged to repair. This is a critical element – if you must buy new collectors, then the project may not be cost-effective, because the collectors are the most expensive part of the system. But the final determination requires an economic analysis that incorporates the value of the fuel that is displaced.

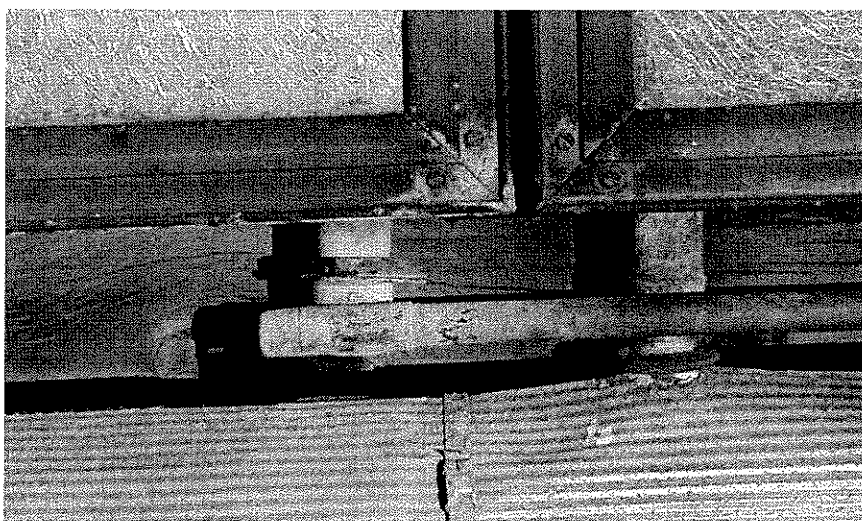


Figure 3. Discoloration in corners if an indication of past leaking in existing hot water systems.

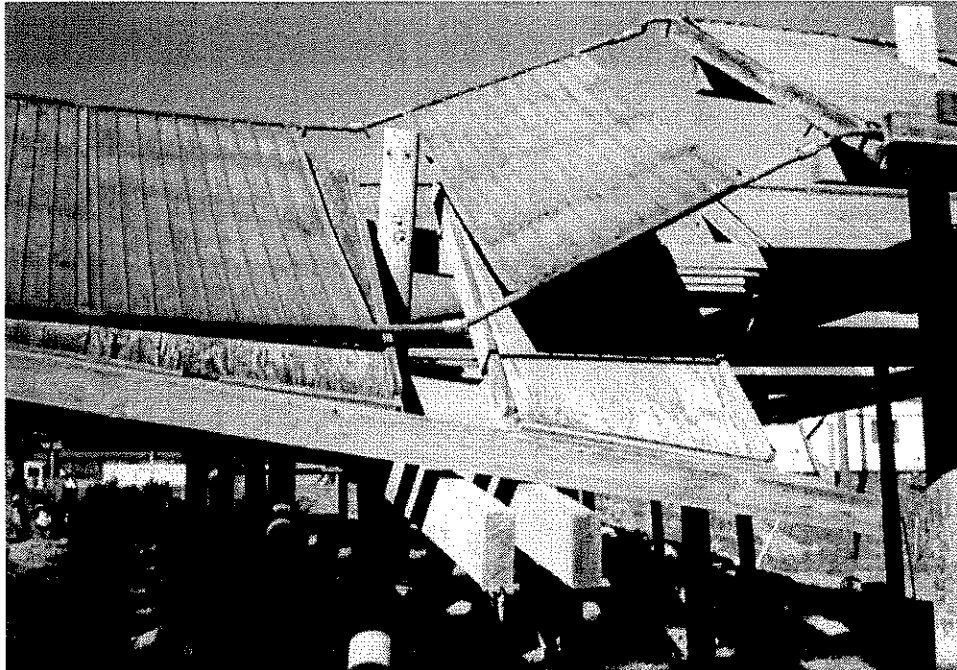


Figure 4. Example of a solar pool system damaged beyond repair.

- What are the collectors constructed from?
 - Copper: This is the best, but could have corrosion problems (see Figures 6 and 7).
 - Aluminum or steel: These could be problematic because they can easily corrode.

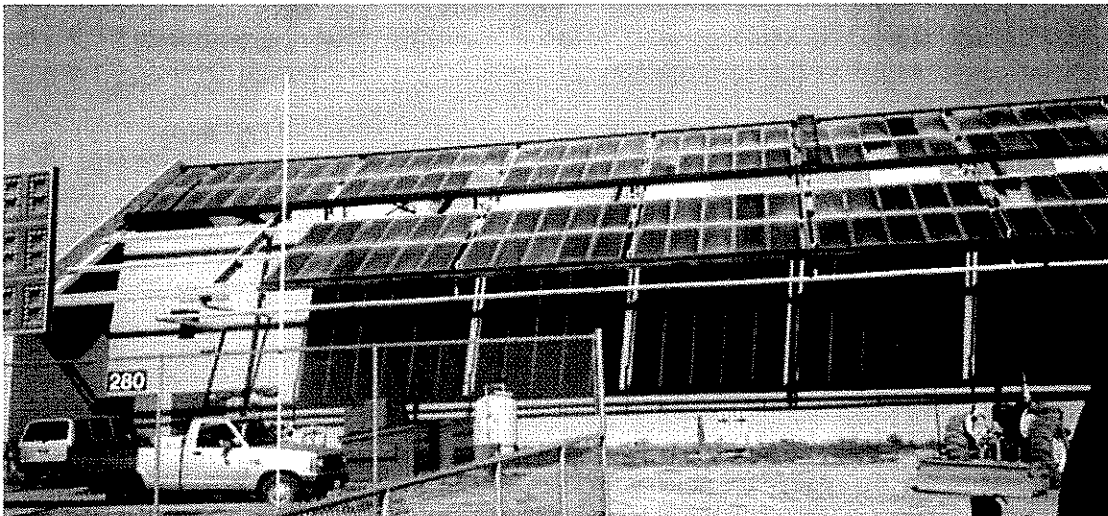


Figure 5. Picture of glazed solar system showing some damage to the collectors. Close up inspection did not reveal leaks. The broken collectors are either reglazed or piped over.

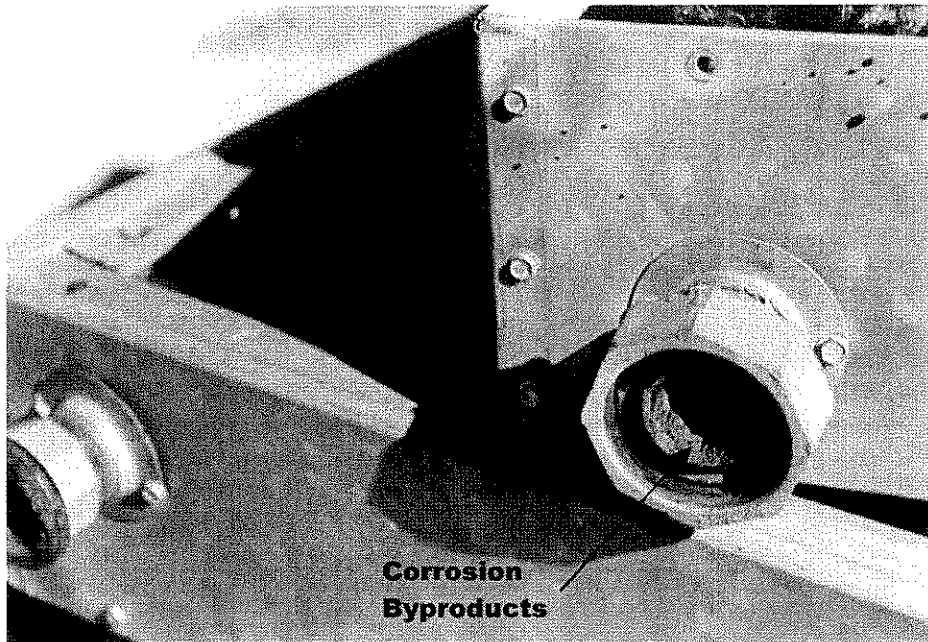


Figure 6. Corrosion byproducts inside collector supply piping.

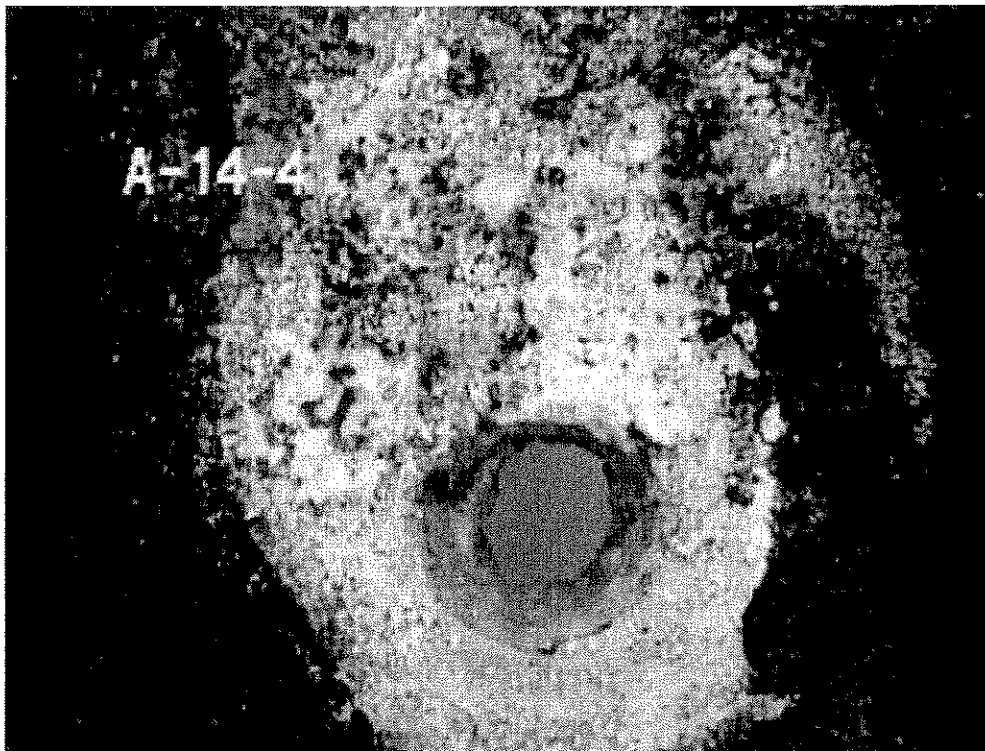


Figure 7. Micrograph of a corrosion pit in a tube of a copper pool collector. This pit was caused when the solar system was subjected to very high pH water for about 12 hours, followed by very low pH water for another 12 hours. Perforation of the tub via the pits quickly followed.

- Plastic: These should be inspected carefully because in an old system the polymer may be of an older generation and may be in a degraded condition. Look for cracks in the polymer and areas of discolorment due to solar exposure.
- What is the condition of the piping? Figure 8 shows old solar piping in relatively undamaged condition. Is there any evidence of leaks, any freeze damage (stretched or expanded pipes), of broken or dented pipes? See Figures 9 and 10 for an example of the kind of damage that can occur. If a dented pipe is noticed, the pipe should be carefully inspected up to and including the nearby joints, which might have been damaged at the same time the dent was created. Investigate any suspected problem areas. Look under pipe insulation, if needed.

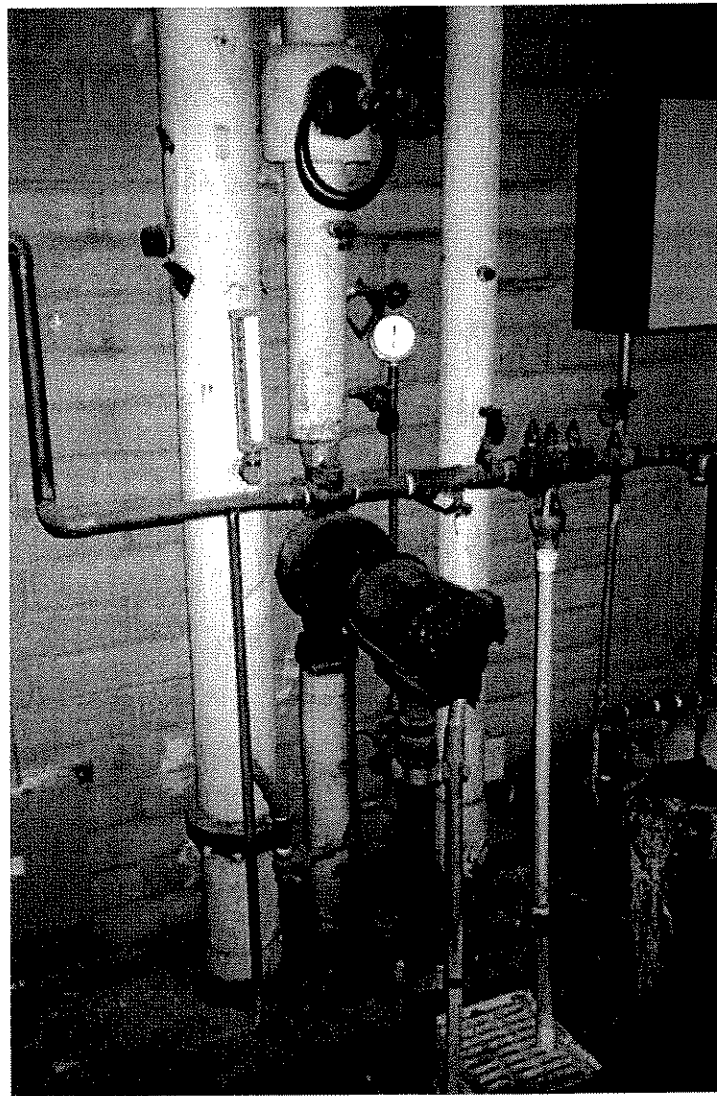


Figure 8. Relatively complete solar pump, piping, and control box in reasonably good condition.

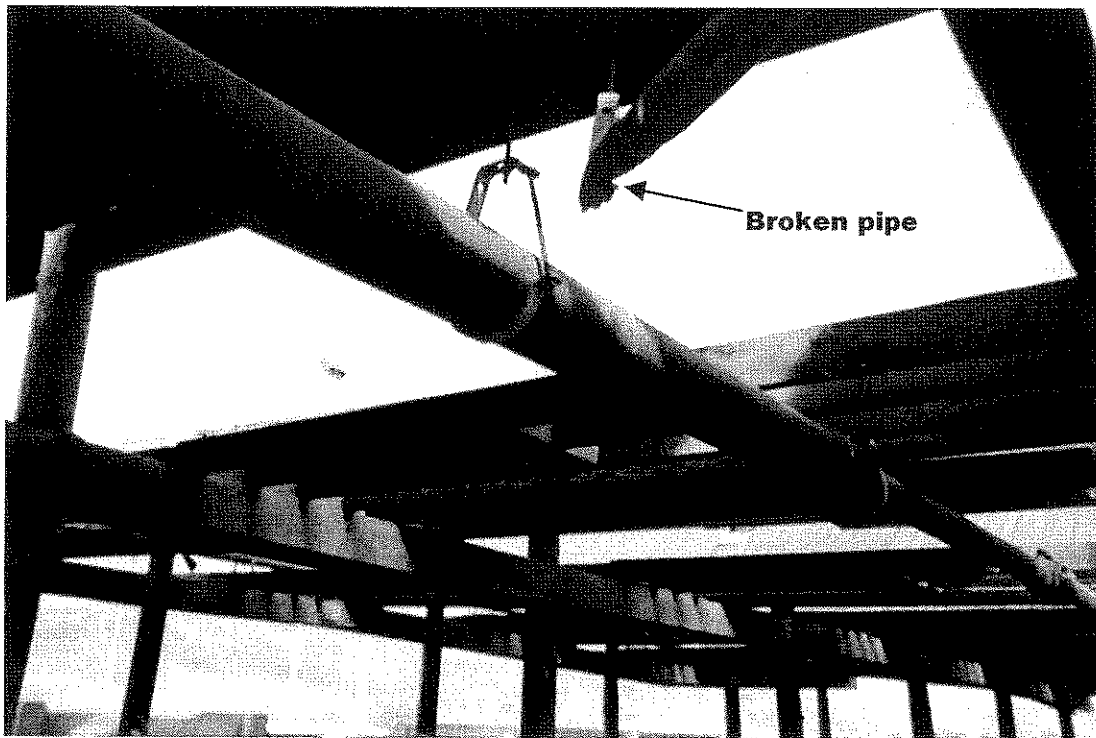


Figure 9. Example of solar supply piping that is damaged.

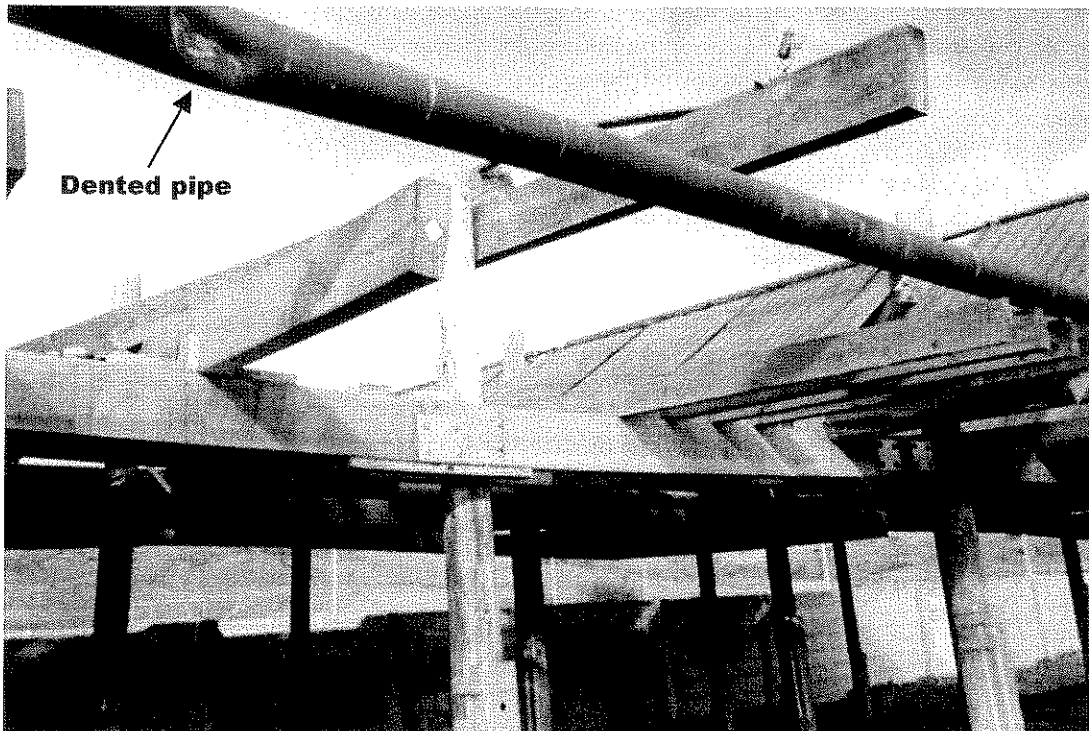


Figure 10. Another example of damaged solar supply piping.

- Pumps: Does shaft turn by hand? Does it run by electricity? (If so, kick it over – run it for 1–2 sec max.). Look for signs of corrosion here, as well (see Figure 11).
- Controls: Are the controls there? Does the control panel look complete? Is there any corrosion on electrical components? Is schematic available? If applicable, perform some electrical checkout by tracing out the wiring to make sure the major components are in place.
- Mounting Structure: Is the structure sound? Look carefully at support structures, especially wooden support structures, where hidden termite damage or dry rot may need to be corrected (see Figure 12). Evidence of termites will include small holes in the wood, sawdust at the base or under the affected wood, and hollowness. Poking a sharp object (large scratch awl) into the wood is a good test for termites. If the awl penetrates significantly, then termite (or rotting, such as dry rot) may have damaged the wood. Structural wood elements can be repaired by professionals by reinforcing the damaged area with steel or pressure-tested lumber. If the damage was due to termites, insecticide is injected into the wood first.

Evaluation Criteria: Generally, if the collectors and other major components are in place and appear to be in reasonably good condition, it is worthwhile to proceed.

2. Look at the minor parts (valves, sensors, insulation). These elements are inexpensive, but can cause system failure if they are not maintained.
 - Valves: Are valves serviceable? Do they work?
 - Sensors: Are they in place? Do they work?
 - Piping insulation: Is it in place? Does it need repairs? Does it have its protective covering in place, especially any outdoor piping?

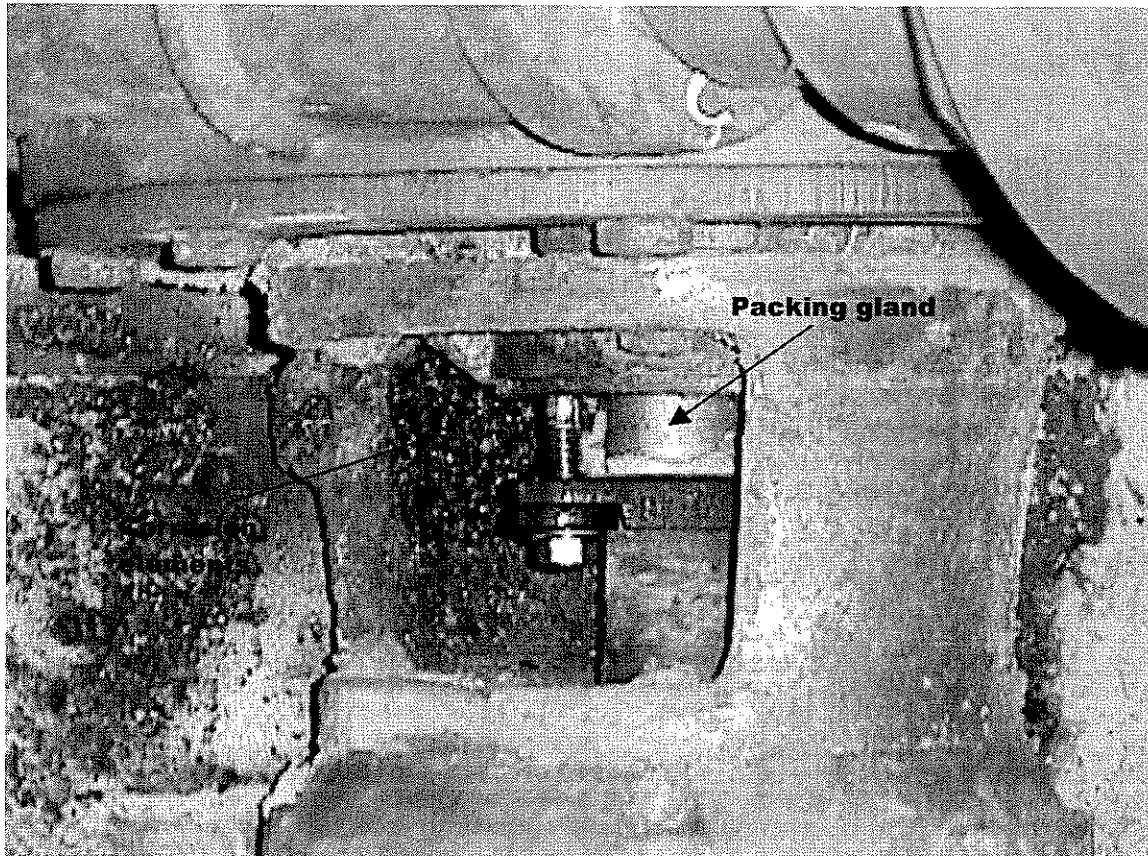


Figure 11. Close-up of pump packing gland that has been leaking and causing corrosion – probably salvageable.



Figure 12. Engineers examined the support structure and extend piping of a solar pool system. Termites were discovered in the posts and had to be supported with steel ties embedded into the ground where collectors are unglazed.

Evaluation Criteria: Minor parts are easy and inexpensive to replace. If these minor parts are in place and operational, it is a plus. If not, they probably should not be used as an excuse to abandon the project.

3. Gather other information by interviewing on-site personnel who know the history of the system.
 - Determine origin of the system, if possible; interview people who operated it, recover log books and review them for information about operation and performance. See Appendix A for the specifications on Camp Pendleton's solar collectors.
 - Determine when it was installed and the manufacturer of major and minor components. This information is useful to order replacement parts.
 - Is hot water pool load or usage of the pool or training tank the same as it was with original system? **If the load has decreased, it may be possible to refurbish a solar panel system even with broken collectors. The broken collectors can be bypassed.**
 - Do the original drawings exist?
 - Do the as-built plans exist?
 - What was the system intended to do? Will it be used in the same manner?

Evaluation Criteria: The most important aspect of this effort is to determine if the solar panel system could be used more or less as originally intended. For example, if the use of the pool has substantially changed so that heating is not needed to the extent of the original design, refurbishing may not be a good idea.

4. Find out who owns and/or is responsible for the building/solar panel system.
 - Is it soon to be reroofed? There is no point in refurbishing a system that will soon be removed.
 - Does the system owner want to keep the system? Without the support of the system owner, a refurbished solar panel system is likely to fall into disrepair.
 - Is the individual who will be responsible for the system committed to its success? Again, even the best solar panel system will fail without routine maintenance.

Evaluation Criteria: It is extremely important to have the full commitment of on-site personnel to the refurbishment effort, especially the maintenance people. Without their full concurrence to the refurbishment objectives, the project is not likely to succeed.

Talk to as many people as you can to gather information about the solar panel system and about the building.

- The energy manager
- The maintenance technician

- The facility manager.
- Are the base personnel aware of Executive Order 13123 that establishes goals to reduce energy consumption (see Appendix B)?

In general, do not be discouraged by negative comments about the system based on hearsay. Many of these comments are probably inaccurate or exaggerated and some of the people may have biases against solar technology.

Find out what kind of system it is. See Figures 13 and 14 for examples.

- Closed-loop with glycol, oil, or water
- Direct open loop, circulating pool water

Evaluation Criteria: Solar pool systems should be simple. Typically, the pool water is circulated through the collectors directly and the water drains back to the pool when the system is not operating.

There are two general types of systems: unglazed collectors or glazed collectors (i.e., collector in an insulated box with a glass cover) for either indoor or outdoor pools. Unglazed collectors are typically used for outdoor, summer-only pools. But in a mild climate, such as MCB Camp Pendleton, unglazed collectors can be used to heat pools year-round.

Glazed collectors are generally used to heat year-round indoor pools or for outdoor pools in more harsh climates where the pool is used during the warmer and cooler parts of the year.

If you find that the system under evaluation generally fits one of these criteria, then you should proceed with the evaluation.

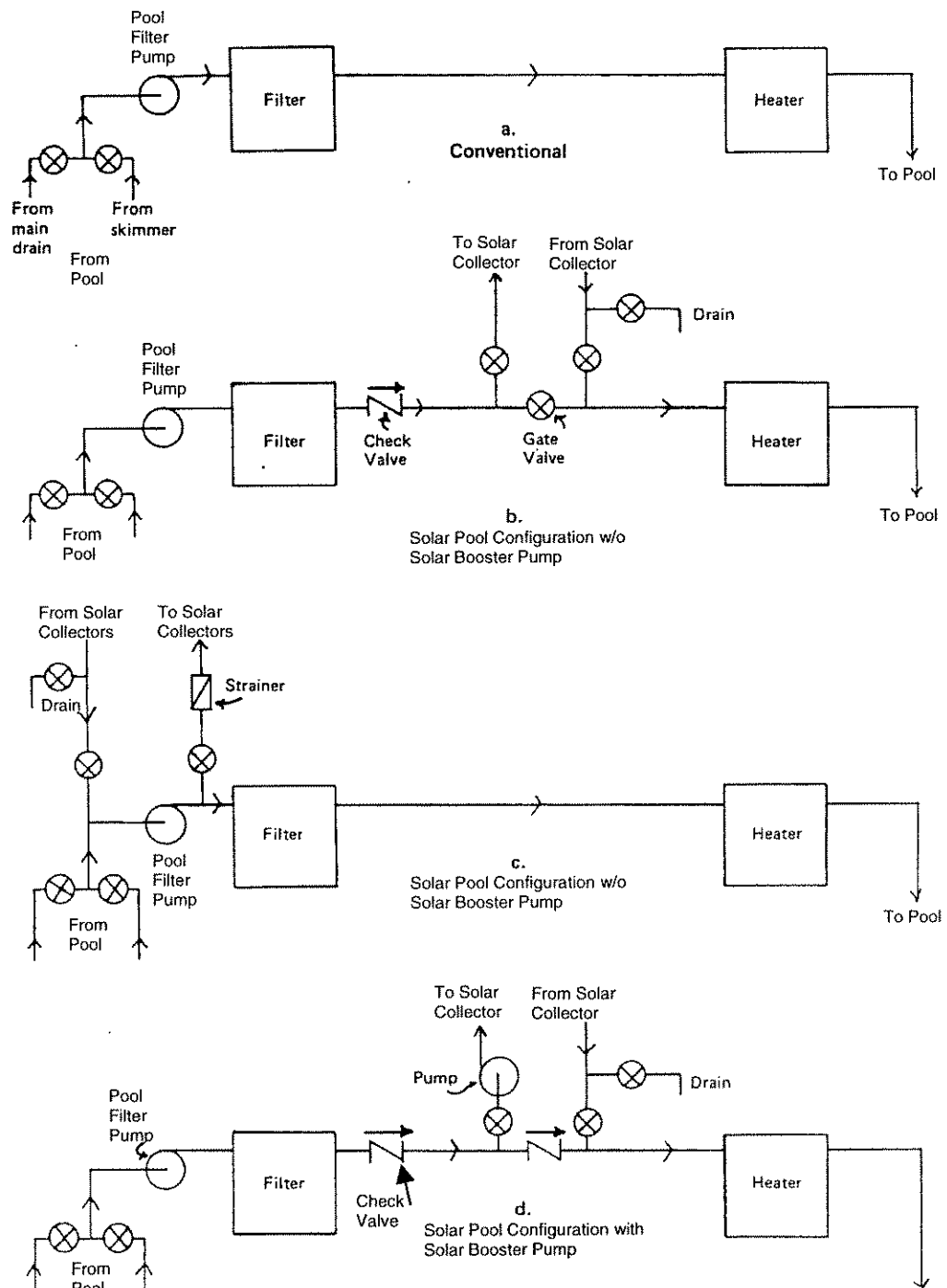


Figure 13. Plumbing Schematics.

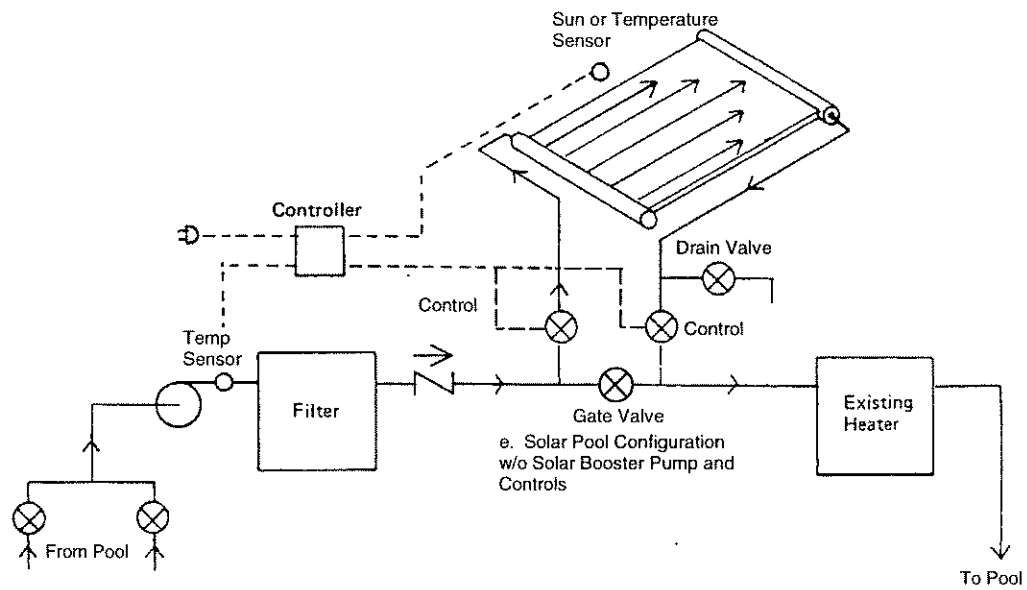


Figure 14. Automatic Control Plumbing Schematic.

STEP 2: TESTING THE SYSTEM

In Step 2, the system is filled with water, pressurized, and checked for leaks. Pumps are checked, and all controls are examined. Corrosion testing is important, because some kinds of water can corrode typical collector metals, such as copper. The concentration of chemicals in pool water can vary rather dramatically from time to time; when concentrations of certain chemicals are high, they can damage solar collectors (see Appendix C: Corrosion). Pool chemicals have virtually no effect on plastic collectors.

1. Put water in the system.

- If there is no pump, you can use a typical garden hose's line pressure. This line pressure is usually higher than designed for the system; use a pressure reducing valve if needed. In most cases, pressurizing the solar system to 50–60 psi will not be harmful, especially for metal collectors. If there is any doubt about the pressure rating of the collectors, it is best to control the pressure to less than 30 psi. Note: Even if the system was originally a closed-loop system, water can be used to check for leaks. Be careful doing this in freezing weather.

NOTE

Testing the system with water is often limited to six months of the year if the system is in a cold winter climate.

Avoid winter, unless it is warm and sunny, and you can drain it back down completely.

Call a specialist if you are limited to cold-weather testing and are unsure of how to proceed.

2. Pressurize the system.

- Hook up a hose and fill the system
- Bleed out the air until it is full of water
- Check for leaks
- Let the system stay pressurized for a few hours, even a day or two.

NOTE

There are several reasons why leaks may have occurred in a collector. It may have been improperly drained.

3. Look for leaks.

- Leave the system pressurized for sufficient time to note all leaks, especially small ones.
- Find where they are coming from. Leaks are most likely to occur at the following:
 - unions or couplings between the collectors
 - the collector fin tubes
 - the collector headers
 - the joint between the collector fin tube and header

4. Test the pump

- Turn it on and see if it works. Does it hold pressure?
- Circulate water through the pump

- Look for pooling of water from seal leaks
- Keep the test simple and low cost, relative to the size of the system. For a small system, don't buy a new pump. If you have a large system (e.g., 700 collectors), it might make sense to borrow/buy and install a pump for testing (see Figure 15).

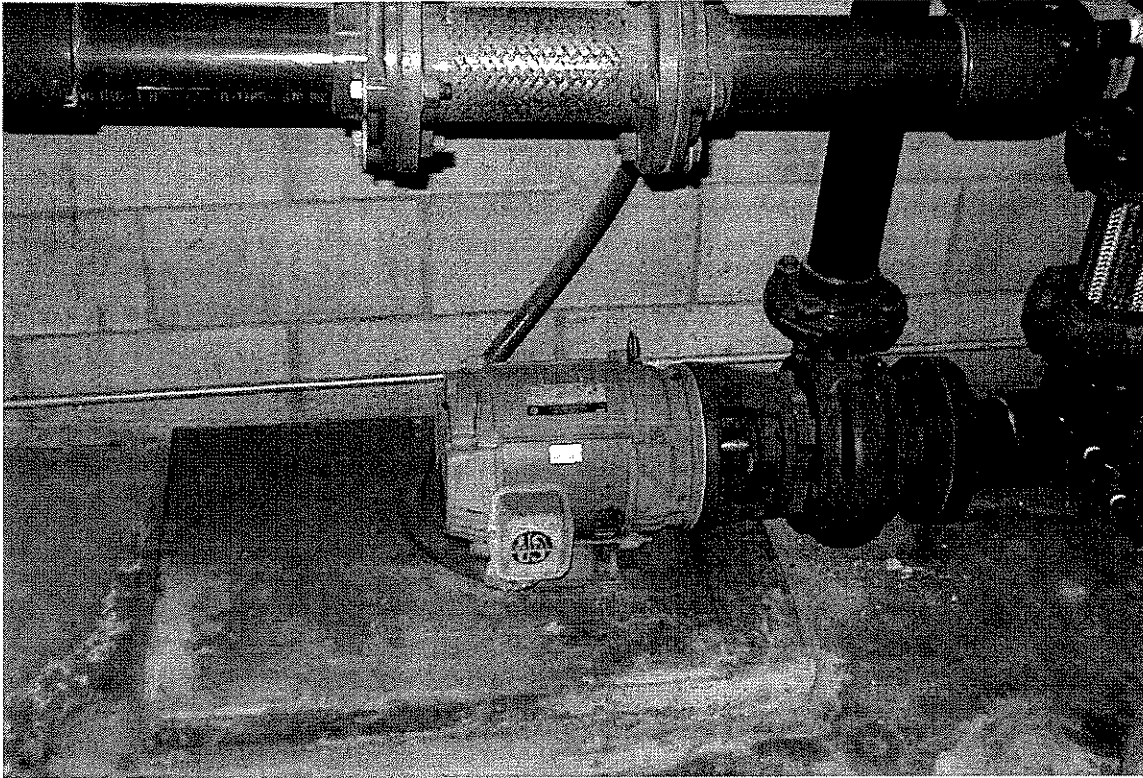


Figure 15. New pump installed for refurbished solar system.

5. Check the control system and see if it works.
 - Simple control panels can be turned on and tested easily, but they may need monitoring over a period of days to ensure proper operation.
 - The more complex control panels are generally unreliable. Unless the controls are virtually intact and the manufacturer is still in business, it makes sense to simplify the control panel to improve its reliability. Unnecessarily complex controls can account for as much as 50% of a refurbishment project. Solar pool heating controls turn on when the sun is up; turn off when the sun is down; and turn off when the pool's temperature is high enough. Do not use the existing EMS system to control the solar system. It is often too unreliable for this function.

CAUTION

Line pressure is 60 to 90 lbs. The pump pressure is around 30 lbs. Some larger systems can withstand 90 lbs.

6. For a large system with many collectors, test a collector that is already out of service. A large system is one with more than 5000 sq. ft. of collectors. Small systems (three to four panels) are too small to sacrifice a collector for testing. This step will determine the potential lifetime of the system.
 - Inspect for corrosion by cutting a cross-section of a collector along the axis of the tube to expose the inside of the tube wall.
 - Copper: Look for noticeable areas of bluish oxide material on copper pipe that indicates corrosion.
 - Steel: Look for rust. It will be obvious (reddish oxide).
 - Plastic: Look for cracks.If you are not sure, call Sandia or a professional contractor.
7. Some items of importance to keep in mind:
 - Sunny days build up temperature and pressure fast; a relief valve may be necessary.
 - Too much pressure build-up can cause damage to the system; a pressurized system left in the sun could explode.
 - Do not abandon your system during testing.
 - Monitor pressure at all times. Existing gauges could be used, but be sure they are working before you depend on them.
 - Install a pressure relief valve or expansion tank, if necessary.
 - Vented steam could scald you; depending on outside temperature, steam may not be visible.
8. See Appendix D for case studies of refurbishment projects at two government institutions.

STEP 3: ANALYZING THE SYSTEM

At Step 3, the team analyzes the problems found in Steps 1 and 2 and develops a refurbishment plan. Using a simple ten-year payback analysis (see Appendix E, Economic Analysis Worksheet), the cost of this plan is compared to an energy budget to determine if bringing the system back into operation is worthwhile. If refurbishment appears cost-effective, as defined by the system owner, the process moves to Step 4.

PERFORMING AN ECONOMIC ANALYSIS AND DEVELOPING A REFURBISHMENT PLAN

Determine if the repairs to the solar system can be completed within your budget.

Get bids or estimates for replacing required components. Some of the necessary components for the system include:

- Pump Repairs: leaking seals, motor burnout, impeller seizes up
- Control Panel Repairs: electronic failure makes control panel inoperable
- Piping and Connector Repairs: leaks, freezing, broken pipes, valve failure, vents get stuck, corrosion
- Collectors Repairs: replace broken glazing; support structures for the collectors; include labor to do work
- Sensors: disconnected, go out of calibration, fails open or closed, sensors are missing

It is prudent to add a 10% contingency to the estimate. Total up the cost for the refurbishment and compare with the budget. If the costs are less than the budget, go forward with the refurbishment. If not, then the effort should probably conclude at this point and the system should be removed.

If the refurbishment process can be completed within the budget, a plan of action can be developed. For example, the work could be done in-house. In this case, determine what areas of the work can be professionally completed in-house and what needs to be contracted out. Note: if the system is fundamentally sound (no leaks, and the control system is operational) and only some of the mechanical systems need upgrading, this is a candidate for in-house repair. If, however, there are repairs needed to the solar collector itself or if the control system needs to be reworked, solar professionals are probably needed.

If the repair work is to be contracted out, it is important to ensure that the bidders list include experienced professionals, preferably ones with solar pool experience. The Solar Energy Industry Association can provide a list of qualified contractors in your area. Contact (703)248-0703 or go to: www.seia.org.

NOTE
An Energy Service Company (ESCO) may be interested in the project.

After total costs are estimated, compute the final payback period using Appendix E.

PERFORMING AN ECONOMIC ANALYSIS FOR MILITARY CONSTRUCTION

Forms DD1391 and DD1391C are military construction project data sheets. These forms list the basic type of information needed to decide if a proposed project will be funded. The information includes the project title, location, estimated total costs, a breakdown of the total costs, a short description, requirements for the project, the current situation, potential impacts if the project is not funded, alternatives considered, and the economic analysis.

The economic analysis is done by a computer program created by the National Institute of Standards and Technology (NIST) called BLCC (Building Life Cycle Cost) for the Federal Energy Management Program (FEMP). The BLCC program estimates the economic evaluation of energy and water conservation projects and renewable energy projects in all federal buildings. The program uses the cost estimates from forms DD1391 and DD1391C, along with the estimated maintenance and fuel costs (if any), and a time interval to estimate the total cost of the project with adjustments for inflation. The same analysis is also done for project alternatives. In the final analysis, the BLCC program estimates the savings-to-investment ratio, the adjusted internal rate of return, and the simple payback in years by comparing the proposed project with alternative project(s). These last numbers are put into forms DD1391 and DD1391C. See Appendix F for more information.

STEP 4: REPAIR THE SYSTEM

Step 4 involves drafting a SOW and hiring a contractor to make the repairs, or if the institution has an internal Facilities Department, performing the work in-house. In such cases, it is important to provide personnel with training in the operation and maintenance of the system, as well as installing a BTU meter (either a commercially-available one or a low-cost one developed by Sandia National Laboratories). BTU meters tell maintenance crew at a glance when the solar panel system is not operating correctly and provide the institution with data to quantify the cost of the fossil fuel that the solar power is displacing.

DEVELOP A STATEMENT OF WORK

SOWs can be brief or fairly detailed, depending on the project involved. Two examples are given below.

Example #1

Pool Refurbishment Statement of Work

The contractor shall remove the existing, damaged, unglazed, copper collectors (4×8 ft nominal). The contractor shall dispose of the copper collectors. If the contractor wishes to salvage the used copper collectors, the contractor may retain the salvage value as an offset to the costs in performing this contract.

The contractor shall install 150, 4×8 ft. (nominal), new, unglazed, polymer collectors on the existing mounting structures, which consist of a raised wooden structure platform located 8-12 ft. above ground level. The mounting surface itself is constructed of exterior plywood and sits on top of the wooden support structure. The orientation of the mounting surface is: approximately south and tilted up from north at an angle approximately equal to the latitude of the site. The collectors shall be installed in strict compliance with the manufactures' installation manuals. The contractor shall provide submittals on the unglazed, polymer collectors to be furnished.

The collectors shall be connected to the existing copper piping that connects the solar system to the 500 gpm pump in the mechanical room.

At the completion of the installation, the contractor shall prepare the collector system for a 48 hour acceptance test to verify that the installation is leak free.

Example #2

Pool Refurbishment Statement of Work

The purpose of this contract is to refurbish the solar pool heating system. This work includes: installing a new control system, installing a system drain from the array to the pool, installing new vents and vacuum valves, configuring system to match the attached piping and instrument drawing (P&ID), and repairing all leaks in the array and associated piping.

The contractor is responsible for providing a fully functioning solar system using the existing collectors and interconnecting piping.

A pre-bid site meeting is mandatory.

The following tasks are included in this project:

- All piping and equipment shall be configured according to the attached P&ID.
- Supply and install a new solar loop pump and motor. This pump shall be a bronze fitted centrifugal pump that delivers 2 gpm of flow to each solar collector. Total flow will be verified by the owner's representative.
- Install drains from supply and return lines. The purpose of the drains is to provide array freeze protection. The supply and return drains will connect to a common line that returns the water to the pool. This line shall be sloped to provide drainage to the pool, and, the line will be beneath the concrete patio and penetrate through the stainless steel lining of the pool, and, the penetration will be through a contractor supplied/installed, stainless steel, bulkhead fitting and sealed to prohibit leakage between the stainless steel liner and the drain line.
- Replace all vent and vacuum valves with new vent and vacuum valves. Supply and install a control system that:
 - Locks out the solar system when the filter pump is not running.
 - Operates the solar system when the filter pump is running and adequate solar potential exists. The control system will open the solar supply and return valves and start the solar loop pump after a one minute time delay. The system will continue to operate until:
 - Filter pump is not running,
 - High temperature limit is reached, or
 - Insufficient solar resource exists.
- Contractor will install owner supplied flow meter and two owner supplied thermowells on each solar system. Flow meter and thermowells are part of an energy monitoring system.
- Provide two sets of operation and maintenance manuals.
- Provide one Field Training Session to base personnel.

This will be a fixed price contract for all work except repair of leaks in existing piping and collectors. Submit unit prices for the following:

- Repair leaks in existing piping.
- Repair leaks in collectors
- Repair/replace collector couplings

- Remove collector and spool through if collector is determined (by owner's representative) to not warrant repair.
- Repair/replace motor operated valves.

The following attached specifications apply, all or in part:

- General Material and Work Requirements
- Piping Systems
- Plumbing
- System Component Checkout and Balance
- Mechanical Systems Demonstration

Minimum Qualifications: Licensed Solar Contractor with five years experience installing commercial size hot water and pool heating systems.

HIRE A CONTRACTOR

Obtain a competitive bid using a bid list of experienced people doing commercial solar pool heating. Try to get the best value for money, not necessarily the lowest bid. Every contractor should be overseen closely to ensure that professional work is done and that the facilities personnel understand what work is being performed.

NOTE

A walk-through is mandatory for anyone who bids on a refurbishment job.

MONITORING THE SYSTEM

The refurbished system needs some indicator of performance. There are several options available. You could install a commercially-available BTU meter¹ (see Figure 16), but these are expensive and can be difficult to install. It might be possible to connect the solar system into the Base Energy Monitoring System. Still another method is to use a simple BTU monitor developed by Sandia National Laboratories (see Figure 19), a low-cost unit specifically designed for monitoring fixed-flow solar pool systems. Plan to record any production from the system as a way to ensure that the system is producing energy after its refurbishment and that it meets its economic expectations. Two BTU meter parts are the flow meter and the temperature sensor. Figures 17 and 18 show examples of orifice and thermal sensors (thermocouples) mounted in thermal wells.

MAINTENANCE AGREEMENT

The refurbishment effort should include a maintenance agreement, either with base facilities maintenance or an outside contractor. A good candidate for the job

¹ Appendix G gives a list of commercial BTU manufacturers.

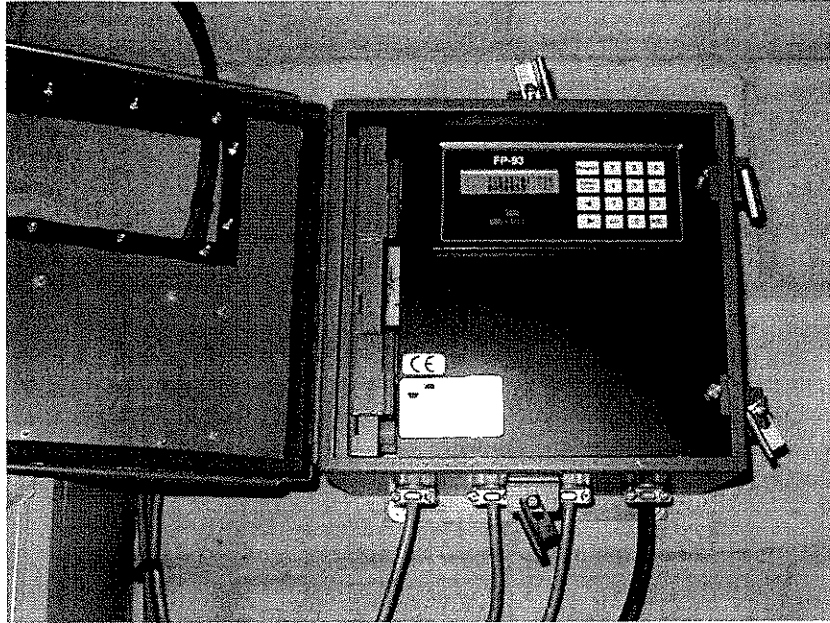


Figure 16. New BTU meter installed in a refurbished solar system.

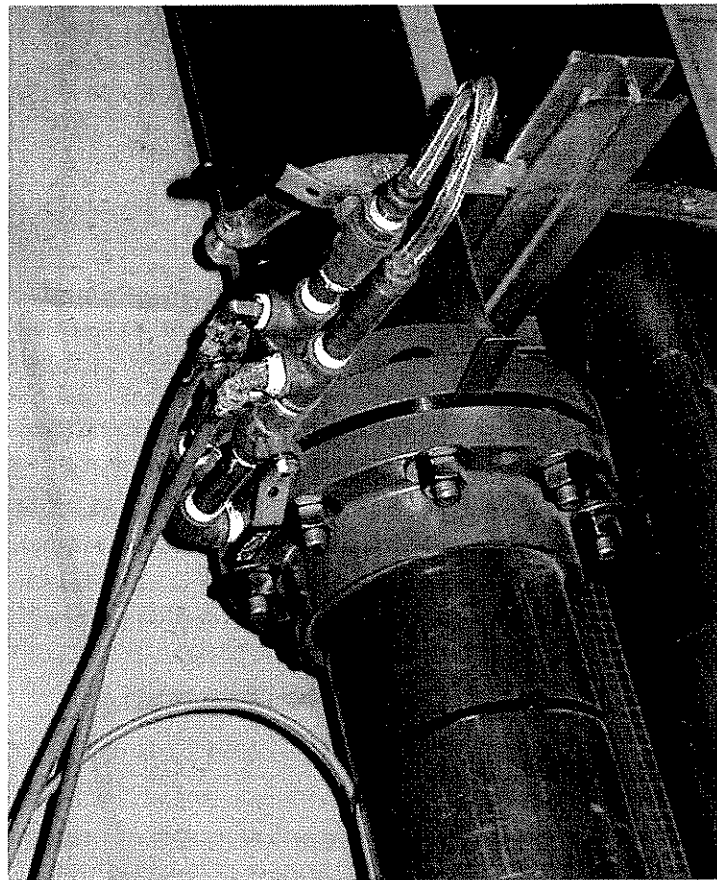


Figure 17. Orifice plate flow meter installed as part of BTU meter system.

[illegible][illegible]

is the refurbishment contractor. For a small system, it will typically not be cost-effective for an outside contractor to do the maintenance.

Maintenance typically requires regular visits to the solar system to inspect its operation and ensure that components are working properly. This contractor could also read the BTU meter. An example of a Maintenance Agreement is given below.

Sample Maintenance Agreement

A. Scope of Effort

This contract will pertain to the following training tanks and recreation pools (total of 7) in Camp Pendleton, California: Area 13, Area 14, Area 17, Area 41, Area 43, Area 53 and Area 62. A map of the areas on Camp Pendleton is in the Offeror's possession.

The Contractor shall supply qualified person(s) who shall visit and inspect each site on average once per month. Each visit shall be conducted on a day with sufficient sunshine so that the solar systems are operating. For example, the schedule for site visits may be on the first workday of the month. However, if the first workday of the month is predicted to be cloudy, the Contractor may reschedule the visit for up to 10 days before or after the scheduled inspection date. However, there should never be more than five weeks between actual inspection dates.

On each inspection the Contractor's personnel shall:

1. Record the BTU count on the BTU meter(s) on site. In the case of Area 17 and 53, the BTU meter is a full-scale meter integrated into the system. In the case of the other Area tanks, the BTU meter is a small unit located on top or near the control box. In some cases both types of meters may be present. A data summary sheet will be provided by Sandia for recording the BTU counts. In addition, the BTU count shall be recorded in the on-site inspection log book that is located at each tank site. The sheet containing the BTU counts shall be mailed or faxed to the Sandia Delegated Representative (SDR) within five days after the completion of the monthly inspection of all of the sites.
2. Inspect operation of the pumps, sensors, valves, and controls by actually operating the devices manually and observe that they are operating properly; including cycling to observe that proper shut down and start up procedures are followed. The test procedure shall include covering the solar sensor to terminate system operation followed by uncovering to initiate operation. The Contractor's personnel shall look and listen for indications of problems, past and present, including leaks, noise from bad bearings, vibrations, indications of shorting or burnt wiring, etc.

3. Inspect the solar array for leaks in the piping or collectors, deterioration in the structure, or other problems.
4. Perform routine maintenance as required, including adjustments to pump and valve packing glands; minor leaks that can be stopped by tightening fittings; tightening electrical terminals to improve electrical conductivity; and any other minor adjustments deemed necessary to improve the performance of the system (e.g., adjusting the set points on the controls).
5. Contractor personnel shall record the results of the inspection in the on-site log book along with a note in the "remarks" section of the BTU log that is supplied by Sandia.
6. Document if any repair is needed that is outside the normal maintenance as outlined above. These repairs include leaks in the collector panel, non-operational sensor, broken pump, etc. This documentation shall include a description of the problem and a recommendation for a fix or solution. This information shall be provided to Sandia along within the data collection sheet and remarks.
7. Contractor shall ensure that personnel be available in the event of an emergency, such as a major leak(s) in the array. Although the site personnel can shut the system down in the event of an emergency, the Contractor shall be on the scene shortly thereafter to ensure proper shutdown and to document the damage. In this even, the Contractor shall notify the Sandia technical monitor (SDR) by phone as soon as possible after the emergency and then document the problem in one of the site log book as well as on a Sandia log sheet that is then mailed or faxed to Sandia.
8. Inquire with the local operator as to the status of the chemical feed machinery at the pool. If the automatic chemical feeders are not operational, then the solar system should be shut down, secured and tagged to prevent it being re-energized by unauthorized personnel. In this event, the Contractor shall record the event in the log book, report it to the SDR by phone and by faxed copy of a documentation sheet.

B. Option Items Separately Priced

Costs for repairs outside of normal maintenance shall be per a fixed schedule indicated below:

Some spare parts will be provided by Sandia to the Contractor for use in repairs. Contractor shall contact the SDR for instructions PRIOR TO making any repairs/replacements.

Item	Unit	Price
Repair/Collector Leaks	ea	\$ 125.00
Repair/replace collector couplings	ea	\$ 85.00
Remove Collector and Spool if it is determined that repairs are not warranted	ea	\$ 100.00
Repair/replace actuator only	ea	\$ 950.00
Replace both motorized actuator and butterfly valve/parts	ea	\$1400.00
Replace valve only (see item above)	ea	\$ 350.00

C. Payments

Interim payments shall be paid after receipt of the Contractor's invoice for the preceding month. The interim payments shall be determined by application of the Category A rate to the reported Standard Equivalent Unit (SEU) hours actually incurred for the effort required in the preceding month.

The final invoice shall be paid after receipt and acceptance of the deliverable described in the paragraph above. The final invoice amount shall be the difference between the total of all interim payments and contract ceiling price, as reduced in accordance with the terms of the following Level of Effort provisions.

TRAINING

The contract should also include training of in-house maintenance personnel in the system. This would include a short course in which the refurbishment contractor briefs the base personnel on the details of the system's operation. All on-site briefing should be mandatory.

O&M MANUAL

The contractor should also be asked to provide the base an O&M Manual once the refurbishment is complete. See Appendix H for an example of an O&M Manual.

CONCLUSIONS

When solar energy was popular in the 1980s, many government institutions rushed to install solar pool systems for heating water and swimming pools. Unfortunately, following installation, regular maintenance was frequently neglected. Consequently, minor problems that caused system malfunctions led many sites to abandon solar power. Today this legacy of abandonment is evident on military bases nationwide, where solar pool systems that have fallen into disrepair go unused. However, solar panel system problems are often easy to identify and inexpensive to repair. Sandia National Laboratories has developed a four-step process for evaluating and refurbishing abandoned solar pool systems.

Step 1 is simply a visual inspection. Minor problems, such as leaks or corrosion, are often visible to a trained eye. Here, the investigative team assesses the overall soundness of the system and reviews its history. If Step 1 reveals the problem, the team proceeds directly to Step 3. If the problem is still not evident, the team proceeds to Step 2.

At Step 2, the system is filled with water, pressurized, and checked for leaks. Pumps are checked, and all controls are examined. Corrosion testing is important because some kinds of water can corrode typical solar metals, such as copper. When Step 2 is complete, the team moves on to Step 3.

At Step 3, the team analyzes the problems found in Steps 1 and 2, then develops a refurbishment plan. Using a simple payback analysis, the cost of this plan is compared to an energy budget to determine if bringing the system back into operation is worthwhile. If refurbishment appears cost-effective, as defined by the system owner, the process moves to Step 4.

Step 4 involves drafting a SOW and hiring a contractor to make the repairs. If the institution has an internal Facilities Department, it may opt to perform the work in-house. In such cases, the team recommends providing personnel with training in the operation and maintenance of the system, as well as installing a low-cost BTU meter. BTU meters tell maintenance crews at a glance when the system isn't operating correctly and provides the institution with data to quantify the value of the fossil fuel solar power is displacing.

By applying this systematic approach, the owner of an abandoned solar panel system can determine if refurbishing the system makes good economic sense. Refurbishment projects can be very cost-effective, some resulting in paybacks as short as six months. With proper maintenance, hot water from refurbished solar pool systems can compete with natural gas.

ACRONYMS AND DEFINITIONS

Acronyms

ADR	Average daily radiation
ASR	Available Solar Resource
BTU	British thermal unit
EMS	Energy Management System
EMS	energy monitoring systems
ESCO	Energy Service Company
FEMP	Federal Energy Management Program
LCCID	Life Cycle Cost Identification
MCB	Marine Corp Base
MMBTU	millions of BTU
NREL	National Renewable Energy Laboratory
O&M	Operation & Maintenance
P&ID	Piping and Instrument Drawing
RFQ	Request for Quotation
SDR	Sandia Delegated Representative
SEU	Standard Equivalent Unit
SIR	Standard Investment Ratio
SNL/NM	Sandia National Laboratories/New Mexico
SOW	statement of work

Definitions

Balance of Plant: Everything except the collector panels and monitoring system (e.g., pumps, controls, valves, etc.)

Closed-Loop System: A solar panel system where its working fluid is separated from the pool water by physical means, such as a heat exchanger.

Drain Back System: A solar panel system in which the working fluid draws out of the collector array whenever the system is not operating.

Glycol System: A closed-loop system in which a glycol/water solution is the working fluid. This type of system is used where collectors may be subjected to freezing.

Average Daily Radiation (ADR): Average daily amount of solar radiation that falls on a surface tilted up from horizontal towards the south at a fixed angle; averaged over the entire year.

Tilt at Latitude: Tilt angle that equals the angle of the latitude at the site. This is the tilt angle at which the maximum amount of yearly radiation can be collected.

Tilt Angle: This is the angle at which solar collectors are tilted up from the horizontal, typically facing south.

REFERENCE DOCUMENTS

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APPENDIX A: SPECIFICATIONS FOR THE SOLAR COLLECTORS ON THE AREA 14 TRAINING TANK AT MCB/CAMP PENDLETON, CA

The collectors used in this project shall meet one of the two following specifications:

Specification 1:

Collectors shall be unglazed highly stabilized polyolefin materials of parallel circular channel design with a nominal size of 4 ft. by 8 ft.

All sub-system components shall be as distributed by the manufacturer for compatible fit and performance with this type of collector.

Solar collectors shall be approved and tested by the Florida Solar Energy Center and shall have a rating of 1012 BTU/sq. ft. per day.

The panels shall have a wet weight not to exceed 1.6 lbs. per sq. ft.

The panels shall be of a non-corrosive design and withstand common swimming pool fluids with associated chemicals.

The panels shall have measured burst pressure of over 300 psi.

The panels shall operate at a flow rate of between 3gpm and 8gpm per panel.

Collectors shall be manufactured in the USA.

The collectors shall be provided with a full 10-year replacement warranty.

Acceptable collectors would include: FAFCO model SI or equivalent.

Specification 2:

Collectors shall be unglazed highly stabilized propylene copolymer with stabilizer combinations providing long term resistance to heat and light; the nominal size of the collector shall be 4 ft. by 8 ft.

All sub-system components shall be as distributed by the manufacturer for compatible fit and performance with this type of collector.

Solar collectors shall be approved and tested by the Florida Solar Energy Center and shall have a rating of 1012 BTU/sq. ft. per day. The system should meet or exceed the criteria for approvals from the following independent labs and approval agencies: International Association of Plumbing and Mechanical Officials (IAPMO), Dade County, and the City of Los Angeles.

The panels shall have a wet weight not to exceed 1.3 lbs. per sq. ft. of the frontal area.

The panels shall be of a non-corrosive design and withstand common swimming pool fluids with associated chemicals.

The panels shall be capable of withstanding an internal static pressure of 85psi at operating temperature, freezing and internal scale accumulation.

The panels shall operate at a flow rate of between 2.5gpm and 10gpm per panel, with a recommended flow rate of 3.25gpm.

Collectors shall be manufactured in the USA.

The collectors shall be provided with a 10-year full replacement warranty.

Acceptable collectors would include: AquaTherm "Ecosun" or equivalent.

APPENDIX B: EXECUTIVE ORDER 13123 GREENING THE GOVERNMENT THROUGH EFFICIENT ENERGY MANAGEMENT

By the authority vested in me as President by the Constitution and the laws of the United States of America, including the National Energy Conservation Policy Act (Public Law 95-619, 92 Stat. 3206, 42 U.S.C. 8252 et seq.), as amended by the Energy Policy Act of 1992 (EPACT) (Public Law 102-486, 106 Stat. 2776), and section 301 of title 3, United States Code, it is hereby ordered as follows:

PART 1—PREAMBLE

Section 101. Federal Leadership. The Federal Government, as the Nation's largest energy consumer, shall significantly improve its energy management in order to save taxpayer dollars and reduce emissions that contribute to air pollution and global climate change. With more than 500,000 buildings, the Federal Government can lead the Nation in energy-efficient building design, construction, and operation. As a major consumer that spends \$200 billion annually on products and services, the Federal Government can promote energy efficiency, water conservation, and the use of renewable energy products, and help foster markets for emerging technologies. In encouraging effective energy management in the Federal Government, this order builds on work begun under EPACT and previous Executive Orders.

PART 2—GOALS

Sec. 201. Greenhouse Gases Reduction Goal. Through life cycle cost-effective energy measures, each agency shall reduce its greenhouse gas emissions attributed to facility energy use by 30 percent by 2010 compared to such emissions levels in 1990. In order to encourage optimal investment in energy improvements, agencies can count greenhouse gas reductions from improvements in nonfacility energy use toward this goal to the extent that these reductions are approved by the Office of Management and Budget (OMB).

Sec. 202. Energy Efficiency Improvement Goals. Through life cycle cost-effective measures, each agency shall reduce energy consumption per gross square foot of its facilities, excluding facilities covered in section 203 of this order, by 30 percent by 2005 and 35 percent by 2010 relative to 1985. No facilities will be exempt from these goals unless they meet new criteria for exemptions, to be issued by the Department of Energy (DOE).

Sec. 203. Industrial and Laboratory Facilities. Through life cycle cost-effective measures, each agency shall reduce energy consumption per square foot, per unit of production, or per other unit as applicable by 20 percent by 2005 and 25 percent by 2010 relative to 1990. No facilities will be exempt from these goals unless they meet new criteria for exemptions, as issued by DOE.

Sec. 204. Renewable Energy. Each agency shall strive to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects and by purchasing electricity from renewable energy sources. In support of the Million Solar Roofs initiative, the Federal Government shall strive to install 2,000 solar energy systems at Federal facilities by the end of 2000, and 20,000 solar energy systems at Federal facilities by 2010.

Sec. 205. Petroleum. Through life cycle cost-effective measures, each agency shall reduce the use of petroleum within its facilities. Agencies may accomplish this reduction by switching to a less greenhouse gas-intensive, nonpetroleum energy source, such as natural gas or renewable energy sources; by eliminating unnecessary fuel use; or by other appropriate methods. Where alternative fuels are not practical or life cycle cost-effective, agencies shall strive to improve the efficiency of their facilities.

Sec. 206. Source Energy. The Federal Government shall strive to reduce total energy use and associated greenhouse gas and other air emissions, as measured at the source. To that end, agencies shall undertake life cycle cost-effective projects in which source energy decreases, even if site energy use increases. In such cases, agencies will receive credit toward energy reduction goals through guidelines developed by DOE.

Sec. 207. Water Conservation. Through life cycle cost-effective measures, agencies shall reduce water consumption and associated energy use in their facilities to reach the goals set under section 503(f) of this order. Where possible, water cost savings and associated energy cost savings shall be included in Energy Savings Performance Contracts and other financing mechanisms.

PART 3—ORGANIZATION AND ACCOUNTABILITY

Sec. 301. Annual Budget Submission. Each agency's budget submission to OMB shall specifically request funding necessary to achieve the goals of this order. Budget submissions shall include the costs associated with encouraging the use of, administering, and fulfilling agency responsibilities under Energy Savings Performance Contracts, utility energy-efficiency service contracts, and other contractual platforms for achieving conservation goals; implementing life cycle cost-effective measures; procuring life cycle cost-effective products; and constructing sustainably designed new buildings, among other energy costs. OMB shall issue guidelines to assist agencies in developing appropriate requests that support sound investments in energy improvements and energy-using products. OMB shall explore the feasibility of establishing a fund that agencies could draw on to finance exemplary energy management activities and investments with higher initial costs but lower life cycle costs. Budget requests to OMB in support of this order must be within each agency's planning guidance level.

Sec. 302. Annual Implementation Plan. Each agency shall develop an annual implementation plan for fulfilling the requirements of this order. Such plans shall be included in the annual reports to the President under section 303 of this order.

Sec. 303. Annual Reports to the President. (a) Each agency shall measure and report its progress in meeting the goals and requirements of this order on an annual basis. Agencies shall follow reporting guidelines as developed under section 306(b) of this order. In order to minimize additional reporting requirements, the guidelines will clarify how the annual report to the President should build on each agency's annual Federal energy reports submitted to DOE and the Congress. Annual reports to the President are due on January 1 of each year beginning in the year 2000.

(b) Each agency's annual report to the President shall describe how the agency is using each of the strategies described in Part 4 of this order to help meet energy and greenhouse gas reduction goals. The annual report to the President shall explain why certain strategies, if any, have not been used. It shall also include a listing and explanation of exempt facilities.

Sec. 304. Designation of Senior Agency Official. Each agency shall designate a senior official, at the Assistant Secretary level or above, to be responsible for meeting the goals and requirements of this order, including preparing the annual report to the President. Such designation shall be reported by each Cabinet Secretary or agency head to the Deputy Director for Management of OMB within 30 days of the date of this order. Designated officials shall participate in the Interagency Energy Policy Committee, described in section 306(d) of this order. The Committee shall communicate its activities to all designated officials to assure proper coordination and achievement of the goals and requirements of this order.

Sec. 305. Designation of Agency Energy Teams. Within 90 days of the date of this order, each agency shall form a technical support team consisting of appropriate procurement, legal, budget, management, and technical representatives to expedite and encourage the agency's use of appropriations, Energy Savings Performance Contracts, and other alternative financing mechanisms necessary to meet the goals and requirements of this order. Agency energy team activities shall be undertaken in collaboration with each agency's representative to the Interagency Energy Management Task force, as described in section 306(c) of this order.

Sec. 306. Interagency Coordination.

(a) Office of Management and Budget. The Deputy Director for Management of OMB, in consultation with DOE, shall be responsible for evaluating each agency's progress in improving energy management and for submitting agency energy scorecards to the President to report progress.

(1) OMB, in consultation with DOE and other agencies, shall develop the agency energy scorecards and scoring system to evaluate each agency's progress in meeting the goals of this order. The scoring criteria shall include the extent to which agencies

are taking advantage of key tools to save energy and reduce greenhouse gas emissions, such as Energy Savings Performance Contracts, utility energy-efficiency service contracts, ENERGY STAR® and other energy-efficient products, renewable energy technologies, electricity from renewable energy sources, and other strategies and requirements listed in Part 4 of this order, as well as overall efficiency and greenhouse gas metrics and use of other innovative energy efficiency practices. The scorecards shall be based on the annual energy reports submitted to the President under section 303 of this order.

(2) The Deputy Director for Management of OMB shall also select outstanding agency energy management team(s), from among candidates nominated by DOE, for a new annual Presidential award for energy efficiency.

(b) Each agency's annual report to the President shall describe how the agency is using each of the strategies described in Part 4 of this order to help meet energy and greenhouse gas reduction

(c) President's Management Council. The President's Management Council (PMC), chaired by the Deputy Director for Management of OMB and consisting of the Chief Operating Officers (usually the Deputy Secretary) of the largest Federal departments and agencies, will periodically discuss agencies' progress in improving Federal energy management.

(d) Interagency Energy Policy Committee. This Committee was established by the Department of Energy Organization Act. It consists of senior agency officials designated in accordance with section 304 of this order. The Committee is responsible for encouraging implementation of energy efficiency policies and practices. The major energy-consuming agencies designated by DOE are required to participate in the Committee. The Committee shall communicate its activities to all designated senior agency officials to promote coordination and achievement of the goals of this order.

(e) Interagency Energy Management Task Force. The Task Force was established by the National Energy Conservation Policy Act. It consists of each agency's chief energy manager. The Committee shall continue to work toward improving agencies' use of energy management tools and sharing information on Federal energy management across agencies.

Sec. 307. Public/Private Advisory Committee. The Secretary of Energy will appoint an advisory committee consisting of representatives from Federal agencies, State governments, energy service companies, utility companies, equipment manufacturers, construction and architectural companies, environmental, energy and consumer groups, and other energy-related organizations. The committee will provide input on Federal energy management, including how to improve use of Energy Savings Performance Contracts and utility energy-efficiency service contracts, improve procurement of ENERGY STAR® and other energy-efficient products, improve building design, reduce process energy use, and enhance applications of efficient and renewable energy technologies at Federal facilities.

Sec. 308. Applicability. This order applies to all Federal departments and agencies. General Services Administration (GSA) is responsible for working with agencies to meet the requirements of this order for those facilities for which GSA has delegated operations and maintenance authority. The Department of Defense (DOD) is subject to this order to the extent that it does not impair or adversely affect military operations and training (including tactical aircraft, ships, weapons systems, combat training, and border security).

PART 4—PROMOTING FEDERAL LEADERSHIP IN ENERGY MANAGEMENT

Sec. 401. Life Cycle Cost Analysis. Agencies shall use life cycle cost analysis in making decisions about their investments in products, services, construction, and other projects to lower the Federal Government's costs and to reduce energy and water consumption. Where appropriate, agencies shall consider the life cycle costs of combinations of projects, particularly to encourage bundling of energy efficiency projects with renewable energy projects. Agencies shall also retire inefficient equipment on an accelerated basis where replacement results in lower life cycle costs. Agencies that minimize life cycle costs with efficiency measures will be recognized in their scorecard evaluations.

Sec. 402. Facility Energy Audits. Agencies shall continue to conduct energy and water audits for approximately 10 percent of their facilities each year, either independently or through Energy Savings Performance Contracts or utility energy-efficiency service contracts.

Sec. 403. Energy Management Strategies and Tools. Agencies shall use a variety of energy management strategies and tools, where life cycle cost-effective, to meet the goals of this order. An agency's use of these strategies and tools shall be taken into account in assessing the agency's progress and formulating its scorecard.

(a) **Financing Mechanisms.** Agencies shall maximize their use of available alternative financing contracting mechanisms, including Energy Savings Performance Contracts and utility energy-efficiency service contracts, when life cycle cost-effective, to reduce energy use and cost in their facilities and operations. Energy Savings Performance Contracts, which are authorized under the National Energy Conservation Policy Act, as modified by the Energy Policy Act of 1992, and utility energy-efficiency service contracts provide significant opportunities for making Federal facilities more energy efficient at no net cost to taxpayers.

(b) **ENERGY STAR® and Other Energy-Efficient Products.**

(1) Agencies shall select, where life cycle cost-effective, ENERGY STAR® and other energy-efficient products when acquiring energy-using products. For product groups where ENERGY STAR® labels are not yet available, agencies shall select products that are in the upper 25 percent of energy efficiency as designated by FEMP. The Environmental Protection Agency (EPA) and DOE shall expedite the process of designating products as ENERGY STAR® and will merge their current efficiency rating procedures.

(2) GSA and the Defense Logistics Agency (DLA), with assistance from EPA and DOE, shall create clear catalogue listings that designate these products in both print and electronic formats. In addition, GSA and DLA shall undertake pilot projects from selected energy-using products to show a "second price tag," which means an accounting of the operating and purchase costs of the item, in both printed and electronic catalogues, and assess the impact of providing this information on Federal purchasing decisions.

(3) Agencies shall incorporate energy-efficient criteria consistent with ENERGY STAR® and other FEMP-designated energy efficiency levels into all guide specifications and project specifications developed for new construction and renovation,, as well as into product specification language developed for Basic Ordering Agreements, Blanket Purchasing Agreements, Government-Wide Acquisition Contracts, and all other purchasing procedures.

(4) DOE and OMB shall also explore the creation of financing agreements with private sector suppliers to provide private funding to offset higher up-front costs of efficient products. Within 9 months of the date of this order, DOE shall report back to the President's Management Council on the viability of such alternative financing options.

(c) ENERGY STAR® Buildings. Agencies shall strive to meet the ENERGY STAR® Building criteria for energy performance and indoor environmental quality in their eligible facilities to the maximum extent practicable by the end of 2002. Agencies may use Energy Savings Performance Contracts, utility energy-efficiency service contracts, or other means to conduct evaluations and make improvements to buildings in order to meet the criteria. Buildings that rank in the top 25 percent in energy efficiency relative to comparable commercial and Federal buildings will receive the ENERGY STAR® Building label. Agencies shall integrate this building rating tool into their general facility audits.

(d) Sustainable Building Design. DOD and GSA, in consultation with DOE and EPA, shall develop sustainable design principles. Agencies shall apply such principles to the siting, design, and construction of new facilities. Agencies shall optimize life cycle costs, pollution, and other environmental and energy costs associated with the construction, life cycle operation, and decommissioning of the facility. Agencies shall consider using Energy Savings Performance Contracts or utility energy-efficiency service contracts to aid them in constructing sustainably designed buildings.

(e) Model Lease Provisions. Agencies entering into leases, including the renegotiation or extension of existing leases, shall incorporate lease provisions that encourage energy and water efficiency wherever life cycle cost-effective. Build-to-suit lease solicitations shall contain criteria encouraging sustainable design and development, energy efficiency, and verification of building performance. Agencies shall include a preference for buildings having the ENERGY STAR® Building label in their selection criteria for acquiring leased buildings. In addition, all agencies shall encourage lessors to apply for the ENERGY STAR® Building label and to explore and implement projects

that would reduce costs to the Federal Government, including projects carried out through the lessors' Energy Savings Performance Contracts or utility energy-efficiency service contracts.

(f) **Industrial Facility Efficiency Improvements.** Agencies shall explore efficiency opportunities in industrial facilities for steam systems, boiler operation, air compressor systems, industrial processes, and fuel switching, including cogeneration and other efficiency and renewable energy technologies.

(g) **Highly Efficient Systems.** Agencies shall implement district energy systems, and other highly efficient systems, in new construction or retrofit projects when life cycle cost-effective. Agencies shall consider combined cooling, heat, and power when upgrading and assessing facility power needs and shall use combined cooling, heat, and power systems when life cycle cost-effective. Agencies shall survey local natural resources to optimize use of available biomass, bioenergy, geothermal, or other naturally occurring energy sources.

(h) **Off-Grid Generation.** Agencies shall use off-grid generation systems, including solar hot water, solar electric, solar outdoor lighting, small wind turbines, fuel cells, and other off-grid alternatives, where such systems are life cycle cost-effective and offer benefits including energy efficiency, pollution prevention, source energy reductions, avoided infrastructure costs, or expedited service.

Sec. 404. Electricity Use. To advance the greenhouse gas and renewable energy goals of this order, and reduce source energy use, each agency shall strive to use electricity from clean, efficient, and renewable energy sources. An agency's efforts in purchasing electricity from efficient and renewable energy sources shall be taken into account in assessing the agency's progress and formulating its scorecard.

(a) **Competitive Power.** Agencies shall take advantage of competitive opportunities in the electricity and natural gas markets to reduce costs and enhance services. Agencies are encouraged to aggregate demand across facilities or agencies to maximize their economic advantage.

(b) **Reduced Greenhouse Gas Intensity of Electric Power.** When selecting electricity providers, agencies shall purchase electricity from sources that use high-efficiency electric generating technologies when life cycle cost-effective. Agencies shall consider the greenhouse gas intensity of the source of the electricity and strive to minimize the greenhouse gas intensity of purchased electricity.

(c) **Purchasing Electricity from Renewable Energy Sources.**

(1) Each agency shall evaluate its current use of electricity from renewable energy sources and report this level in its annual report to the President. Based on this review, each agency should adopt policies and pursue projects that increase the use of such electricity. Agencies should include provisions for the purchase of electricity from renewable energy sources as a component of their requests for bids whenever

procuring electricity. Agencies may use savings from energy efficiency projects to pay additional incremental costs of electricity from renewable energy sources.

(2) In evaluating opportunities to comply with this section, agencies should consider my Administration's goal of tripling nonhydroelectric renewable energy capacity in the United States by 2010, the renewable portfolio standard specified in the restructuring guidelines for the State in which the facility is located, GSA's efforts to make electricity from renewable energy sources available to Federal electricity purchasers, and EPA's guidelines on crediting renewable energy power in implementation of Clean Air Act standards.

Sec. 405. Mobile Equipment. Each agency shall seek to improve the design, construction, and operation of its mobile equipment, and shall implement all life cycle cost-effective energy efficiency measures that result in cost savings while improving mission performance. To the extent that such measures are life cycle cost-effective, agencies shall consider enhanced use of alternative or renewable-based fuels.

Sec. 406. Management and Government Performance. Agencies shall use the following management strategies in meeting the goals of this order.

(a) Awards. Agencies shall use employee incentive programs to reward exceptional performance in implementing this order.

(b) Performance Evaluations. Agencies shall include successful implementation of provisions of this order in areas such as Energy Savings Performance Contracts, sustainable design, energy-efficient procurement, energy efficiency, water conservation, and renewable energy projects in the position descriptions and performance evaluations of agency heads, members of the agency energy team, principal program managers, heads of field offices, facility managers, energy managers, and other appropriate employees.

(c) Retention of Savings and Rebates. Agencies granted statutory authority to retain a portion of savings generated from efficient energy and water management are encouraged to permit the retention of the savings at the facility or site where the savings occur to provide greater incentive for that facility and its site managers to undertake more energy management initiatives, invest in renewable energy systems, and purchase electricity from renewable energy sources.

(d) Training and Education. Agencies shall ensure that all appropriate personnel receive training for implementing this order.

(1) DOE, DOD, and GSA shall provide relevant training or training materials for those programs that they make available to all Federal agencies relating to the energy management strategies contained in this order.

(2) The Federal Acquisition Institute and the Defense Acquisition University shall incorporate into existing procurement courses information on Federal energy management tools, including Energy Savings Performance Contracts, utility energy-

efficiency service contracts, ENERGY STAR® and other energy-efficient products, and life cycle cost analysis.

(3) All agencies are encouraged to develop outreach programs that include education, training, and promotion of ENERGY STAR® and other energy-efficient products for Federal purchase card users. These programs may include promotions with billing statements, user training, catalogue awareness, and exploration of vendor data collection of purchases.

(e) **Showcase Facilities.** Agencies shall designate exemplary new and existing facilities with significant public access and exposure as showcase facilities to highlight energy or water efficiency and renewable energy improvements.

PART 5-TECHNICAL ASSISTANCE

Sec. 501. Within 120 days of this order, the Director of OMB shall:

(a) Develop and issue guidance to agency budget officers on preparation of annual funding requests associated with the implementation of the order for the FY 2001 budget;

(b) In collaboration with the Secretary of Energy, explain to agencies how to retain savings and reinvest in other energy and water management projects; and

(c) In collaboration with the Secretary of Energy through the Office of Federal Procurement Policy, periodically brief agency procurement executives on the use of Federal energy management tools, including Energy Savings Performance Contracts, utility energy-efficiency service contracts, and procurement of energy-efficient products and electricity from renewable energy sources.

Sec. 502. Within 180 days of this order, the Secretary of Energy, in collaboration with other agency heads, shall:

(a) Issue guidelines to assist agencies in measuring energy per square foot, per unit of production, or other applicable unit in industrial, laboratory, research, and other energy-intensive facilities;

(b) Establish criteria for determining which facilities are exempt from the order. In addition, DOE must provide guidance for agencies to report proposed exemptions;

(c) Develop guidance to assist agencies in calculating appropriate energy baselines for previously exempt facilities and facilities occupied after 1990 in order to measure progress toward goals;

(d) Issue guidance to clarify how agencies determine the life cycle cost for investments required by the order, including how to compare different energy and fuel options and assess the current tools;

(e) Issue guidance for providing credit toward energy efficiency goals for cost-effective projects where source energy use declines but site energy use increases; and

(f) Provide guidance to assist each agency to determine a baseline of water consumption.

Sec. 503. Within 1 year of this order, the Secretary of Energy, in collaboration with other agency heads, shall:

(a) Provide guidance for counting renewable and highly efficient energy projects and purchases of electricity from renewable and highly efficient energy sources toward agencies' progress in reaching greenhouse gas and energy reduction goals;

(b) Develop goals for the amount of energy generated at Federal facilities from renewable energy technologies;

(c) Support efforts to develop standards for the certification of low environmental impact hydropower facilities in order to facilitate the Federal purchase of such power;

(d) Work with GSA and DLA to develop a plan for purchasing advanced energy products in bulk quantities for use in by multiple agencies;

(e) Issue guidelines for agency use estimating the greenhouse gas emissions attributable to facility energy use. These guidelines shall include emissions associated with the production, transportation, and use of energy consumed in Federal facilities; and

(f) Establish water conservation goals for Federal agencies.

Sec. 504. Within 120 days of this order, the Secretary of Defense and the Administrator of GSA, in consultation with other agency heads, shall develop and issue sustainable design and development principles for the siting, design, and construction of new facilities.

Sec. 505. Within 180 days of this order, the Administrator of GSA, in collaboration with the Secretary of Defense, the Secretary of Energy, and other agency heads, shall:

(a) Develop and issue guidance to assist agencies in ensuring that all project cost estimates, bids, and agency budget requests for design, construction and renovation of facilities are based on life cycle costs. Incentives for contractors involved in facility design and construction must be structured to encourage the contractors to design and build at the lowest life cycle cost;

(b) Make information available on opportunities to purchase electricity from renewable energy sources as defined by this order. This information should accommodate relevant State regulations and be updated periodically based on technological advances and market changes, at least every 2 years;

(c) Develop Internet-based tools for both GSA and DLA customers to assist individual and agency purchasers in identifying and purchasing ENERGY STAR® and other energy-efficient products for acquisition; and

(d) Develop model lease provisions that incorporate energy efficiency and sustainable design.

PART 6—GENERAL PROVISIONS

Sec. 601. Compliance by Independent Agencies. Independent agencies are encouraged to comply with the provisions of this order.

Sec. 602. Waivers. If an agency determines that a provision in this order is inconsistent with its mission, the agency may ask DOE for a waiver of the provision. DOE will include a list of any waivers it grants in its Federal Energy Management Programs annual report to the Congress.

Sec. 603. Scope. (a) This order is intended only to improve the internal management of the Executive branch and is not intended to create any right, benefit, or trust responsibility, substantive or procedural, enforceable by law by a party against the United States, its agencies, its officers, or any other person.

(b) This order applies to agency facilities in any State of the United States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the United States Virgin Islands, the Northern Mariana Islands and any other territory or possession over which the United States has jurisdiction. Agencies with facilities outside of these areas, however, are encouraged to make best efforts to comply with the goals of this order for those facilities. In addition, agencies can report energy improvements made outside the United States in their annual report to the President; these improvements may be considered in agency scorecard evaluations.

Sec. 604. Revocations. Executive Order 12902 of March 9, 1994, Executive Order 12759 of April 17, 1991, and Executive Order 12845 of April 21, 1993, are revoked.

Sec. 605. Amendments to Federal Regulations. The Federal Acquisition Regulation and other Federal regulations shall be amended to reflect changes made by this order, including an amendment to facilitate agency purchases of electricity from renewable energy sources.

PART 7—DEFINITIONS

For the purposes of this order:

Sec. 701. “Acquisition” means acquiring by contract supplies or services (including construction) by and for the use of the Federal Government through purchase or lease, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated. Acquisition begins at the point when agency needs are established and includes the description of requirements to satisfy agency needs,

solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fulfilling agency needs by contract.

Sec. 702. “Agency” means an Executive agency as defined in 5 U.S.C. 105. For the purpose of this order, military departments, as defined in 5 U.S.C. 102, are covered under-the auspices of DOD.

Sec. 703. “Energy Savings Performance Contract” means a contract that provides for the performance of services for the design, acquisition, financing, installation, testing, operation, and where appropriate, maintenance and repair, of an identified energy or water conservation measure or series of measures at one or more locations. Such contracts shall provide that the contractor must incur costs of implementing energy savings measures, including at least the cost (if any) incurred in making energy audits, acquiring and installing equipment, and training personnel in exchange for a predetermined share of the value of the energy savings directly resulting from implementation of such measures during the term of the contract. Payment to the contractor is contingent upon realizing a guaranteed stream of future energy and cost savings. All additional savings will accrue to the Federal Government.

Sec. 704. “Exempt facility” or “Exempt mobile equipment” means a facility or a piece of mobile equipment for which an agency uses DOE-established criteria to determine that compliance with the Energy Policy Act of 1992 or this order is not practical.

Sec. 705. “Facility” means any individual building or collection of buildings, grounds, or structure, as well as any fixture or part thereof, including the associated energy- or water-consuming support systems, which is constructed, renovated, or purchased in whole or in part for use by the Federal Government. It includes leased facilities where the Federal Government has a purchase option or facilities planned for purchase. In any provision of this order, the term “facility” also includes any building 100 percent leased for use by the Federal Government where the Federal Government pays directly or indirectly for the utility costs associated with its leased space. The term also includes Government-owned contractor-operated facilities.

Sec. 706. “Industrial facility” means any fixed equipment, building, or complex for production, manufacturing, or other processes that uses large amounts of capital equipment in connection with, or as part of, any process or system, and within which the majority of energy use is not devoted to the heating, cooling, lighting, ventilation, or to service the water heating energy load requirements of the facility.

Sec. 707. “Life cycle costs” means the sum of the present values of investment costs, capital costs, installation costs, energy costs, operating costs, maintenance costs, and disposal costs, over the lifetime of the project, product, or measure. Additional guidance on measuring life cycle costs is specified in 10 C.F.R. 436.19.

Sec. 708. “Life cycle cost-effective” means the life cycle costs of a product, project, or measure are estimated to be equal to or less than the base case (i.e., current or standard practice or product). Additional guidance on measuring cost-effectiveness is specified in 10 C.F.R.436.18 (a), (b), and (c), 436.20, and 436.21.

Sec. 709. “Mobile equipment” means all Federally owned ships, aircraft, and nonroad vehicles.

Sec. 710. “Renewable energy” means energy produced by solar, wind, geothermal, and biomass power.

Sec. 711. “Renewable energy technology” means technologies that use renewable energy to provide light, heat, cooling, or mechanical or electrical energy for use in facilities or other activities. The term also means the use of integrated whole-building designs that rely upon renewable energy resources, including passive solar design.

Sec. 712. “Source energy” means the energy that is used at a site and consumed in producing and in delivering energy to a site, including, but not limited to, power generation, transmission, and distribution losses, and that is used to perform a specific function, such as space conditioning, lighting or water heating.

Sec. 713. “Utility” means public agencies and privately owned companies that market, generate, and/or distribute energy or water, including electricity, natural gas, manufactured gas, steam, hot water, and chilled water as commodities for public use and that provide the service under Federal, State, or local regulated authority to all authorized customers. Utilities include Federally owned nonprofit producers, municipal organizations, and investor or privately owned producers regulated by a State and/or the Federal Government; cooperatives owned by members and providing services mostly to their members; and other nonprofit State and local government agencies serving in this capacity.

Sec. 714. “Utility energy-efficiency service” means demand-side management services provided by a utility to improve the efficiency of use of the commodity (electricity, gas, etc.) being distributed. Services can include, but are not limited to, energy efficiency and renewable energy project auditing, financing, design, installation, operation, maintenance, and monitoring.

WILLIAM J. CLINTON
THE WHITE HOUSE,

June 3, 1999

APPENDIX C: CORROSION

Sandia National Laboratories

P.O. Box 5800
Albuquerque, New Mexico 87185-0703

date: November 24, 1998
to: TREC Committee and John Krajewski
from: D. F. Menicucci, MS 0704, Dept. 6201
subject: Corrosion in Copper Solar Collectors—Some Lessons Learned

As you may know, we at Sandia have been increasingly aware of corrosion of copper solar collectors, especially open loop systems that have been repeatedly exposed to oxygenated water (either tap water or pool water). This is a major concern during a refurbishment effort where older copper collectors are brought into operation after sitting idle for many years. Since refurbishment of solar systems is potentially very cost effective, there is increasing interest in these projects. We have studied the problem and are now in a position to outline our understanding of the problem and to propose some mitigation strategies.

Based on information we have gathered to date, we are now recommending that corrosion analysis and water quality testing be included as an essential preliminary step in any refurbishment effort. Closed loop systems are often not as critical, but they should be tested also. The testing is not complex or expensive, but does require experienced people and a lab with adequate testing facilities. Specific recommendations are outlined immediately below. Supporting information follows these recommendations.

Based on these experiences we offer the following conclusions and recommendations:

- 1) Refurbishment projects can be very cost effective, some resulting in paybacks as short as six months. They should be pursued aggressively.
- 2) Any open loop system considered for refurbishment should be tested for corrosion (especially for evidence of active pitting that can lead to perforations).
- 3) Any open loop system considered for refurbishment should have the water quality tested for conditions that lead to corrosion, especially extreme pH, high amounts of dissolved solids, and high amounts of carbon dioxide. If the water quality is poor, then either treat the water or redesign the system in a closed loop.
- 4) For any operating open loop system, monitor the water quality and control exposure of poor quality water to the solar collector. Especially avoid exposing the copper collector to extreme pH conditions that can occur in pools when chemicals are hand fed or during chlorine shock treatments occasionally used to purify the pool.
- 5) Any closed loop system considered for refurbishment should be considered for testing for evidence of corrosion. In general, these systems are less vulnerable than open loop systems. Therefore, on a newer system, the tests may consist of visual inspection of the headers and examination of corrosion products in any residual fluid. In older systems, testing should include an in-lab examination similar to one performed for an open loop system.

The conclusions are based on lessons that we would like to share with you. One of the most important findings is that the quality of the water that the copper collector is exposed affects its lifetime. Copper collectors tolerate fluids with pH values in the neutral range. However, extreme pH (either high or low) can cause catastrophic damage.

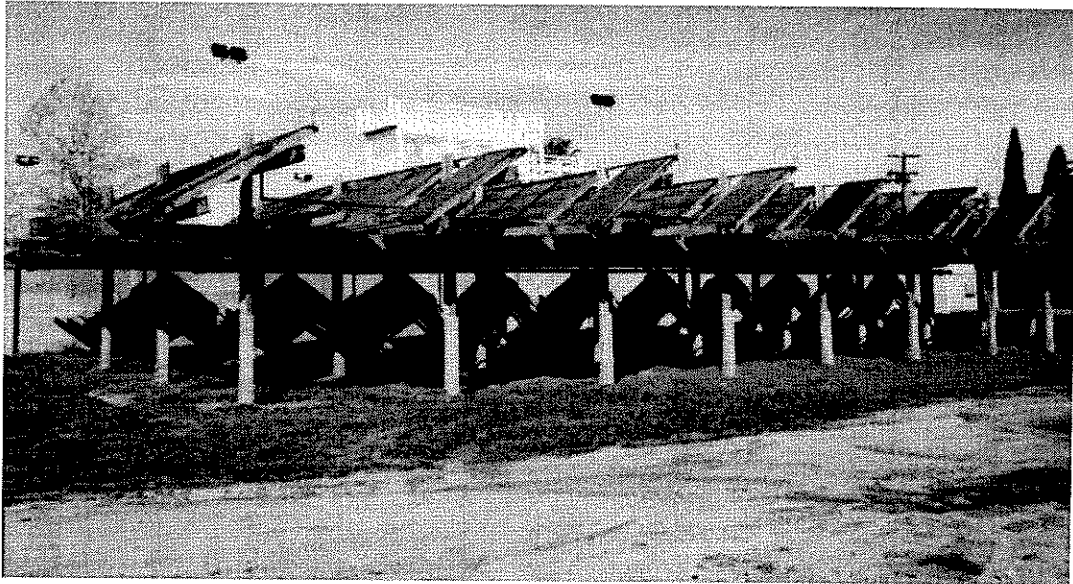
Let me cite a specific example. As you may have heard, we have been refurbishing the training tank solar systems at MCB/Camp Pendleton. There are seven large solar pool systems that have been brought back into operation. We had tested the arrays for corrosion before we did the upgrade and all of the copper looked reasonably good (some pitting, but nothing serious). All of the systems were brought back into operation this summer and were operating properly. One day, we received an emergency call from the operator of one of the pools (area 14) saying that there had suddenly appeared hundreds of leaks in the collector. We took the system off line and engaged in a systematic investigation of the events. We analyzed sections of the failed tubes and interviewed the operators. Our reconstruction of the events is as follows: During one weekend during the summer when the solar system was operating, the automatic chemical feeder failed. During the time of that failure, the pool operators took appropriate action to keep the pool safe and healthy by maintaining the pool chemistry. However, to do this they simply poured the chemicals directly into the pool over the edge. They did this in an area where the chemicals could be sucked directly into the solar system and expose the array to an extreme pH. Since there was no automatic feeder, the pH was hard to control and when the pH went too high, they countered it with other chemicals, also spilled over the edge. This exposed the array to the opposite extreme pH. As a result, the combination of these two events caused the copper to begin corroding and within a period of 72 hours hundreds of the locations had perforated and were leaking.

In analyzing these pits, Dr. Sorensen, our corrosion expert, theorized that the extreme pH events had removed the normal passivation layer that forms on the walls of the copper tubes and protects the copper from corrosion. This layer looks like soot on the inside walls of the tubes but is relatively hard. Once removed, the extreme pH conditions began pitting through the copper. Since pool water is heavily oxygenated, the process of corrosion is very fast and powerful. Dr. Sorensen cross sectioned many of the perforations and based on the materials present around the pit, concluded that the full perforation process was very rapid, no more than a week and as short as two days, probably in the neighborhood of 72 hours.

This is not an isolated event. Four years ago, a new, copper integral storage system was installed in a prison to heat water for the mess hall. Integral systems preheat the incoming tap water that eventually flow through the conventional hot water heater. It is possible for fresh tap water to be in contact with the collector for many hours during stagnant periods. In this case, the water contained a high amount of dissolved solids, including manganese and other metals. It also had very high amount of carbon dioxide. We theorized that during the stagnant periods, some of the dissolved solids precipitated out and fell to the bottom of the ICS collector tubes. These materials initiated some corrosion pits that eventually perforated. Within a period of two weeks, the entire 5000 square foot array had failed. No water quality tests had been conducted prior to the event (other than normal ones for drinkability). Subsequently, tests confirmed that although the water met drinking standards, its constituents were harmful to copper. At our urging, tests were conducted on the standard piping throughout the prison and pitting was evident throughout; none had perforated because the walls were thicker than those in the solar collector. Now, the solar system is being replaced with a closed loop one, a new water treatment plant is on-line, and the copper plumbing is being replaced.

APPENDIX D: TWO CASE STUDIES

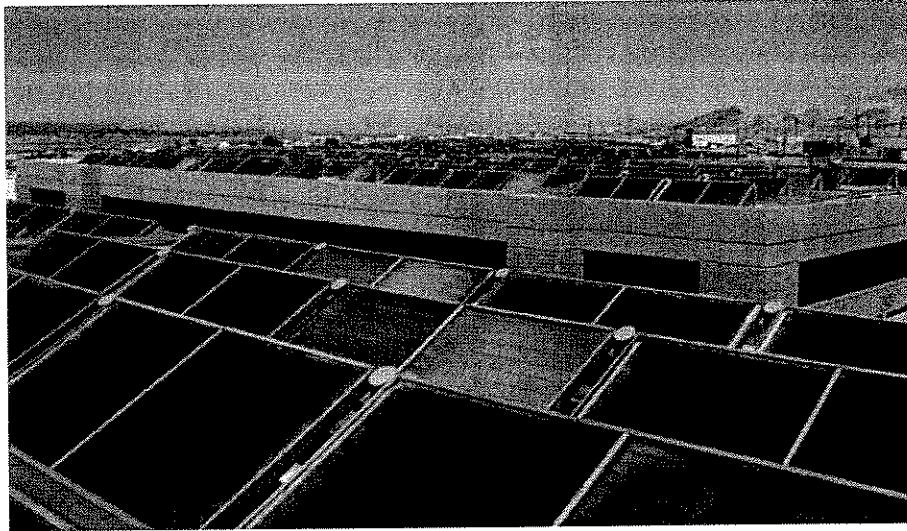
Like many government facilities, Marine Corp Base (MCB) Camp Pendleton and MCB Twenty-Nine Palms received funding in the 1980s to outfit buildings with solar panels. Also like many government facilities, these solar panels systems fell into disrepair when minor maintenance problems were untreated or misdiagnosed.



Training Tank Solar Array System at MCB Camp Pendleton

The Marine Corp approached Sandia National Laboratories in 1997 about upgrading and refurbishing the solar pool systems at Camp Pendleton, where solar arrays were designed to heat training tanks/pools, and Twenty-Nine Palms, where large array systems were intended to provide domestic hot water for barracks. Both systems consisted of copper collectors in fairly good condition. Dave Menicucci and Earl Rush were enlisted to perform the four-step analysis they developed for solar refurbishment projects, and identified six candidates for refurbishment at Camp Pendleton and four candidates at Twenty-Nine Palms. A combination of Federal Energy Management Program (FEMP) and Marine Corp funding was used to refurbish the solar pool systems at Camp Pendleton, but FEMP funds and in-kind support from the MCB only covered a single system at Twenty-Nine Palms.

Refurbishment began immediately at Camp Pendleton with the training tanks. The solar panel system was installed in the early 1980s, but had never been used. Training tanks are essentially large swimming pools where Marines practice underwater maneuvers. The tanks are heated not for the Marines' comfort, but for the trainers, who stay in the water for hours at a time. If the water isn't sufficiently heated, the trainers risk hypothermia.



Solar Panel Array for Barracks at MCB Twenty-Nine Palms

By 1998, the solar pool systems were saving energy for the MCB – a maximum potential of 3,800 million BTUs per year. Solar power has since demonstrated its usefulness by keeping the training tanks warm when the fossil-fuel heater failed, which allowed training to continue as scheduled. Without solar power, the entire operation would have been moved to another site, at considerable expense.

The story was similar at Twenty-Nine Palms, where solar panels installed in the mid-1980s were taken offline for an unknown reason and subsequently abandoned. In 1998, the Department of Energy's FEMP provided funding to refurbish one of the systems. Although FEMP funding only provided for one 80-panel refurbishment project at Twenty-Nine Palms, the work went so well that the MCB leveraged in its own resources and personnel to extend the funds and refurbish another system. By providing their own staff, time, and materials (and because the copper collectors were in better shape than originally thought), Twenty-Nine Palms still had enough money left over to refurbish a third solar panel system – three for the price of one. The refurbishment on the third system continues today and is nearing completion. Recently, the fossil-fuel system was turned off in two of the three refurbished systems, and the solar arrays successfully provided all the hot water for the barracks between September and November, 1999 – at a savings of roughly 2,750 million BTUs per year.

APPENDIX E: ECONOMIC ANALYSIS WORKSHEET

This worksheet will provide guidance in developing a budget for the refurbishment effort that, if implemented, will produce a cost-effective system. Cost-effectiveness is defined as a system that, after refurbishment, produces energy savings that, when accumulated over a specified period of time, equals the investment to refurbish the system. The user can choose the payback time period. Ten years is the payback period most typically chosen for military projects.

The following steps are used to determine the refurbishment budget.

1. Determine the solar resource for your site. The best way to determine your solar resource is to consult the NREL manual *Solar Radiation Data Manual for Flat Plate and Concentrating Collectors*, [NREL, 1994]. However, you can also use the information presented in this Appendix.

If using the NREL manual, select the city with most similar climate and elevation nearest the refurbishment site. From the table for fixed flat plate collectors, select the tilt angle that is closest to the tilt angle of the system to be refurbished.

If the refurbished system is to be operated year-round, select the average annual daily radiation (ADR). This value is used in the computations below. If the refurbished system is to be operated for only part of the year, select the ADR for each of the months that the system is to operate. Sum these values and divide by the number of months. Convert the ADR from KWH/m² to BTU/ft² by multiplying by 317.38. This value is used in the following computations.

Table E-1 can be used to determine your solar resource as well. If the solar pool system is used year-round, then select the city with the most similar climate and elevation that is nearest to the refurbishment system. Figure E-1 shows the cities in Table E-1 in relation to each other. Select the associated average daily solar radiation value. This value will be used in the following computations. If the solar panel system is used for a fraction of the year and you are using the tabled values in this manual, consider the following guidelines. In southern latitudes, especially in the southwest, the ADR in winter is about XX% less than the average ADR values in the table. The summer volumes are about XX% greater than the ADR. In northern latitudes, such as the upper midwest and New England, the summer ADR may be the average ADR and the winter ADR may be 50% of the summer. In most locations, the ADR during the spring and fall are typically close to the ADR for the

Table E-1. Thirty-Year Average of Daily Solar Radiation, 1961-1990, for Flat-Plate Collectors Facing South Tilted at Latitude (from NREL, 1994)

State	City	Kilowatt Hours per m ²	BTU per ft ²
AK	Annette	3.0	952.1
AK	Barrow	2.5	793.5
AK	Bethel	3.1	983.9
AK	Bettles	3.2	1015.6
AK	Big Delta	3.4	1079.1
AK	Fairbanks	3.3	1047.4
AK	Cold Bay	2.4	761.7
AK	Gulkana	3.6	1142.6
AK	King Salmon	3.0	952.1
AK	Kodiak	3.1	983.9
AK	Kotzebue	3.2	1015.6
AK	McGrath	3.2	1015.6
AK	Nome	3.3	1047.4
AK	St. Paul Island	2.5	793.5
AK	Talkeetna	3.3	1047.4
AK	Yakutat	2.7	856.9
AK	Anchorage	3.0	952.1
AL	Birmingham	4.9	1555.2
AL	Huntsville	4.8	1523.4
AL	Mobile	4.9	1555.2
AL	Montgomery	5.1	1618.6
AR	Fort Smith	5.1	1618.6
AR	Little Rock	5.0	1586.9
AZ	Flagstaff	6.0	1904.3
AZ	Prescott	6.1	1936.0
AZ	Tucson	6.5	2063.0
AZ	Phoenix	6.5	2063.0
CA	Arcata	4.4	1396.5
CA	Bakersfield	5.7	1809.1
CA	Dagget	6.6	2094.7
CA	Fresno	5.7	1809.1
CA	Long Beach	5.6	1777.3
CA	Sacramento	5.5	1745.6
CA	San Diego	5.7	1809.1
CA	San Francisco	5.4	1713.9
CA	Santa Maria	5.9	1872.5
CA	Los Angeles	5.6	1777.3
CO	Alamosa	6.3	1999.5
CO	Colorado Springs	5.6	1777.3

State	City	Kilowatt Hours per m ²	BTU per ft ²
CO	Eagle	5.5	1745.6
CO	Grand Junction	5.8	1840.8
CO	Pueblo	5.9	1872.5
CO	Boulder/Denver	5.5	1745.6
CT	Bridgeport	4.4	1396.5
CT	Hartford	4.4	1396.5
DE	Wilmington	4.6	1459.9
FL	Daytona Beach	5.2	1650.4
FL	Jacksonville	5.0	1586.9
FL	Key West	5.5	1745.5
FL	Tallahassee	5.1	1618.6
FL	Tampa	5.3	1682.1
FL	West Palm Beach	5.1	1618.6
FL	Miami	5.2	1650.4
GA	Athens	5.1	1618.6
GA	Augusta	5.1	1618.6
GA	Columbus	5.1	1618.6
GA	Macon	5.1	1618.6
GA	Savannah	5.1	1618.6
GA	Atlanta	5.1	1618.6
HI	Hilo	4.8	1523.4
HI	Kahului	5.8	1840.8
HI	Lihue	5.2	1650.4
HI	Honolulu	5.7	1809.1
IA	Mason City	4.6	1459.9
IA	Sioux City	4.8	1523.4
IA	Waterloo	4.6	1459.9
IA	Des Moines	4.8	1523.4
ID	Pocatello	5.0	1586.9
ID	Boise	5.1	1618.6
IL	Moline	4.6	1459.9
IL	Peoria	4.6	1459.9
IL	Rockford	4.5	1428.2
IL	Springfield	4.8	1523.4
IL	Chicago	4.4	1396.5
IN	Evansville	4.7	1491.7
IN	Fort Wayne	4.3	1364.7
IN	South Bend	4.2	1333.0
IN	Indianapolis	4.6	1459.9
KS	Dodge City	5.6	1777.3
KS	Goodland	5.6	1777.3
KS	Wichita	5.2	1650.4

State	City	Kilowatt Hours per m ²	BTU per ft ²
KS	Topeka	4.9	1555.2
KY	Covington	4.5	1428.2
KY	Lexington	4.5	1428.2
KY	Louisville	4.6	1459.9
LA	Baton Rouge	4.9	1555.2
LA	Lake Charles	5.0	1586.9
LA	Shreveport	5.1	1618.6
LA	New Orleans	5.0	1586.9
MA	Worcester	4.5	1428.2
MA	Boston	4.6	1459.9
MD	Baltimore	4.6	1459.9
ME	Caribou	4.2	1333.0
ME	Portland	4.6	1459.9
MI	Alpena	4.2	1333.0
MI	Flint	4.1	1301.3
MI	Grand Rapids	4.2	1333.0
MI	Houghton	4.1	1301.3
MI	Lansing	4.2	1333.0
MI	Muskegon	4.2	1333.0
MI	Sault Ste Marie	4.2	1333.0
MI	Traverse City	4.1	1301.3
MI	Detroit	4.2	1333.0
MN	Duluth	4.4	1396.5
MN	International Falls	4.3	1364.7
MN	Rochester	4.5	1428.2
MN	St. Cloud	4.6	1459.9
MN	Minneapolis/St. Paul	4.6	1459.9
MO	Columbia	4.9	1555.2
MO	Kansas City	4.0	1269.5
MO	Springfield	4.9	1555.2
MO	St. Louis	4.8	1523.4
MS	Meridan	4.9	1555.2
MS	Jackson	5.1	1618.6
MT	Cut Bank	4.8	1523.4
MT	Glasgow	4.7	1491.7
MT	Great Falls	4.8	1523.4
MT	Helena	4.7	1491.7
MT	Kalispell	4.1	1301.2
MT	Louistown	4.7	1491.7
MT	Miles City	5.0	1586.9
MT	Missoula	4.3	1364.7
MT	Billings	5.0	1586.9

State	City	Kilowatt Hours per m ²	BTU per ft ²
NC	Ashville	4.9	1555.2
NC	Cape Hatteras	5.0	1586.9
NC	Charlotte	5.0	1586.9
NC	Greensboro	5.0	1586.9
NC	Wilmington	5.0	1586.9
NC	Raleigh	5.0	1586.9
ND	Fargo	4.6	1459.9
ND	Minot	4.7	1491.7
ND	Bismarck	4.9	1555.2
NE	Grand Island	5.2	1650.4
NE	Norfolk	5.0	1586.9
NE	North Platte	5.3	1682.1
NE	Scottsbluff	5.3	1682.1
NE	Omaha	4.9	1555.2
NH	Concord	4.6	1459.9
NJ	Newark	4.5	1428.2
NJ	Atlantic City	4.6	1459.9
NM	Tucumcari	6.0	1904.3
NM	Albuquerque	6.4	2031.2
NV	Elko	5.4	1713.9
NV	Ely	5.8	1840.8
NV	Reno	5.8	1840.8
NV	Tonopah	6.1	1936.0
NV	Winnemucca	5.5	1745.6
NV	Las Vegas	6.5	2063.0
NY	Albany	4.3	1364.7
NY	Binghamton	4.1	1301.3
NY	Buffalo	4.1	1301.3
NY	Massena	4.3	1364.7
NY	Rochester	4.1	1301.3
NY	Syracuse	4.1	1301.3
NY	New York City	4.6	1459.9
OH	Akron.Canton	4.1	1301.3
OH	Cleveland	4.1	1301.3
OH	Dayton	4.4	1396.5
OH	Mansfield	4.2	1333.0
OH	Youngstown	3.9	1237.8
OH	Toledo	4.4	1396.5
OH	Columbus	4.2	1333.0
OK	Tulsa	5.1	1618.6
OK	Oklahoma City	5.4	1713.9
OR	Astoria	3.6	1142.6

State	City	Kilowatt Hours per m ²	BTU per ft ²
OR	Burns	5.1	1618.6
OR	Eugene	4.1	1301.3
OR	Medford	4.9	1555.2
OR	North Bend	4.4	1396.5
OR	Pendleton	4.7	1491.7
OR	Redmond/Bend	5.1	1618.6
OR	Salem	4.1	1301.3
OR	Portland	3.9	1237.8
PA	Allentown	4.4	1396.5
PA	Bradford	4.1	1301.3
PA	Erie	4.1	1301.3
PA	Harrisburg	4.5	1428.2
PA	Philadelphia	4.6	1459.9
PA	Wilkes-Barre	4.2	1333.0
PA	Williamsport	4.2	1333.0
PA	Pittsburgh	4.2	1333.0
PI	Guam	5.1	1618.6
PR	San Juan	5.5	1745.6
RI	Providence	4.5	1428.2
SC	Charleston	5.1	1618.6
SC	Greenville	5.0	1586.9
SC	Columbia	5.1	1618.6
SD	Huron	4.8	1523.4
SD	Rapid City	5.2	1650.4
SD	Sioux Falls	4.8	1523.4
SD	Pierre	5.0	1586.9
TN	Bristol	4.6	1459.9
TN	Chattanooga	4.7	1491.7
TN	Knoxville	4.7	1491.7
TN	Memphis	5.0	1586.9
TN	Nashville	4.9	1555.2
TX	Abilene	5.7	1809.1
TX	Amarillo	5.8	1840.8
TX	Austin	5.3	1682.1
TX	Brownsville	5.3	1682.1
TX	Corpus Christi	4.9	1555.2
TX	El Paso	6.5	2063.0
TX	Houston	4.8	1523.4
TX	Lubbock	5.8	1840.8
TX	Lufkin	5.1	1618.6
TX	Midland/Odessa	6.0	1904.3
TX	Port Arthur	4.9	1555.2

State	City	Kilowatt Hours per m ²	BTU per ft ²
TX	San Angelo	5.7	1809.1
TX	San Antonio	5.4	1713.8
TX	Victoria	4.9	1555.2
TX	Waco	5.4	1713.8
TX	Wichita Falls	5.5	1745.6
TX	Ft. Worth	5.4	1713.8
UT	Cedar City	5.9	1872.5
UT	Salt Lake City	5.3	1682.1
VA	Lynchburg	5.0	1586.9
VA	Norfolk	4.8	1523.4
VA	Roanoke	4.8	1523.4
VA	Sterling	4.7	1491.7
VA	Richmond	4.8	1523.4
VT	Burlington	4.3	1364.7
WA	Olympia	3.6	1142.6
WA	Quillayute	3.4	1079.1
WA	Spokane	4.5	1428.2
WA	Yakima	4.8	1523.4
WA	Seattle	3.7	1174.3
WI	Eau Clair	4.4	1396.5
WI	Green Bay	4.4	1396.5
WI	La Crosse	4.5	1428.2
WI	Milwaukee	4.5	1428.2
WI	Madison	4.5	1428.2
WV	Elkins	4.2	1333.0
WV	Huntington	4.3	1364.7
WV	Charleston	4.4	1396.5
WY	Cheyenne	5.3	1682.1
WY	Lander	5.6	1777.3
WY	Rock Springs	5.5	1745.6
WY	Sheridan	5.0	1586.9
WY	Casper	5.3	1682.1

year. Depending on the portion of the year when the solar panel system is operating, and the part of the country, adjust the yearly ADR up or down as needed.

It is important to remember, however, that this is a rough calculation, done for the purpose of determining a rough economic analysis and is not used for system sizing. Therefore, it is not essential to be extremely accurate. In fact, it is often best to be conservative in these estimates by using a slightly lower ADR than is anticipated. This will help build some additional capacity into the estimates.

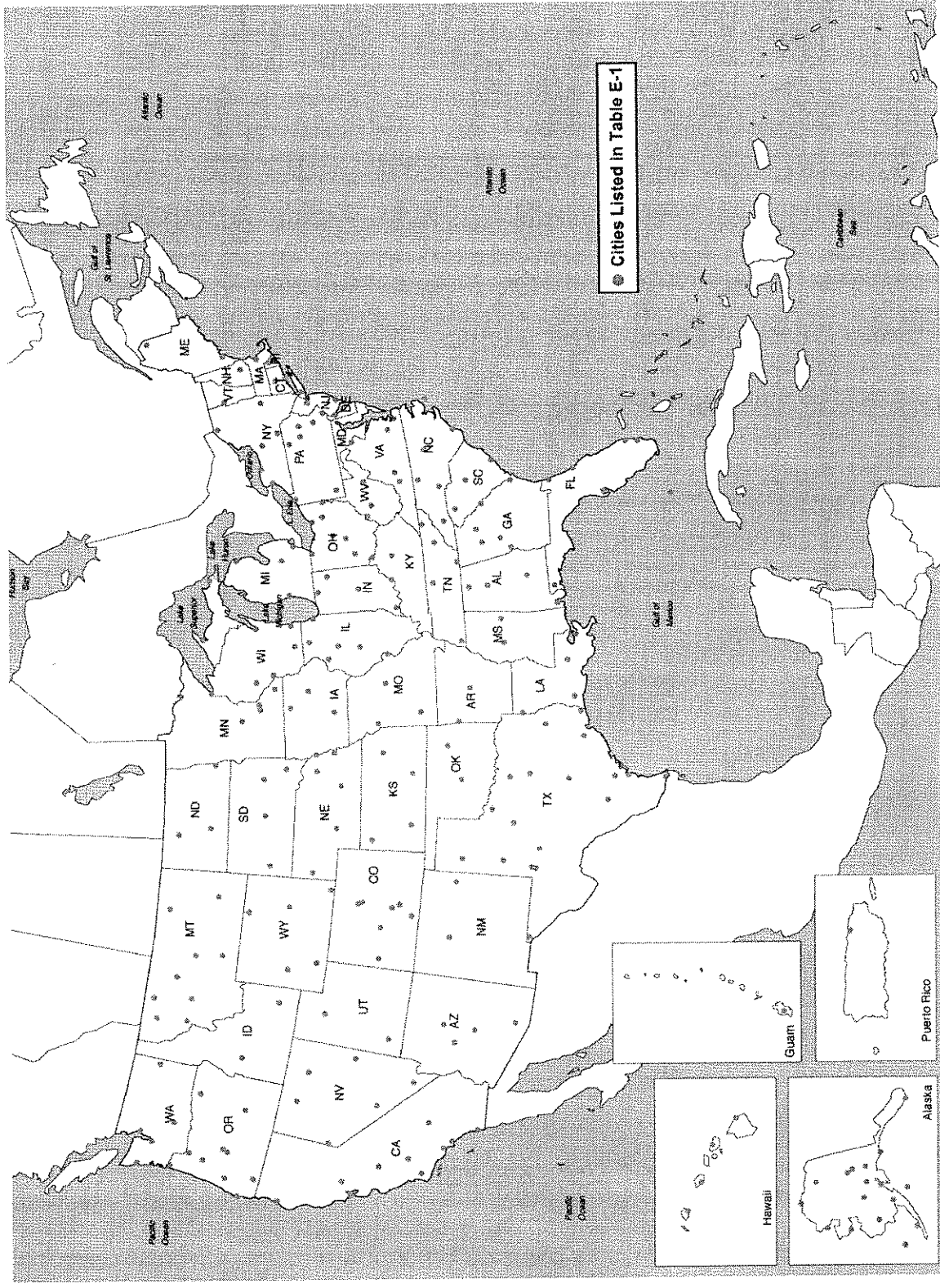


Figure E1. Cities in Table E-1 in relation to each other.

2. Determine the number of square feet of collector surface by measuring the size of one collector and then multiplying by the number of collectors. Convert the value to square feet. Compute the Available Solar Resource (ASR) for the solar system: a) adjust the ADR for time of year operation, if needed, b) multiply the adjusted ADR by the square ft of the collector to estimate the total daily radiation in on the collectors, c) multiply this result by 100,000 to convert it to millions of BTU (MMBTU), round it off to 1 place to the right of the decimal point, and d) multiply the result of "c" above by the number of days the system is scheduled to operate.
3. Estimate the actual collector performance by multiplying the ASR by the collector solar-to-heat efficiency (0.45 is a reasonable average for most year-round use collector systems. If the collector is unglazed (i.e., the collector is not housed in a box with a glass cover), and it operates only in the warm season, the average efficiency could be assumed to be 50% (0.50). This is the Total Energy Production in MMBTU (millions of BTU).
4. Compute the Value of the Displaced Energy produced by the solar system. Determine the cost of the fossil fuel used to heat the pool when the solar system is not operating. Existing energy bills are the best source of this information. Look for the total amount of the bill and then divide it by the total number of units of fuel developed. This is the cost per unit of fuel. Note that the cost may vary from month to month, so take an average over the period when the solar system is operating. Next, compute the cost per BTU for the fossil fuel. Compute the cost by first estimating the number of BTUs per unit of fuel delivered to the site. Use Tables E2 and E3 as a guide. Compute the cost per BTU by dividing the total cost per unit of fuel by the number of BTUs per unit. Multiply the result by 1,000,000 and the result is the cost per million BTU.
5. Next, estimate the overall Boiler or Heater efficiency (i.e., the efficiency of converting the heat from the combustion of the fossil fuel to usable heat). Use the following values as a guide about boiler/heater efficiency.

Old boiler or heater (>20 years); efficiency \cong 60% (0.60)

New boiler or heater; efficiency \cong 75% (0.75)

Table E-2. BTU Contents of Gas

Type of Gas	Energy Content per Unit
Natural	1045 BTU per cubic foot
Propane (Refinery)	2504 BTU per cubic foot
Propane	91,000 BTU per gal.
Butane (Refinery)	3184 BTU per cubic foot

Table E-3. Grades of Fuel Oil (Approx. Figures)

Number	Name	BTU per Gallon (Gross)
1	Distillate	136,000
2	Domestic	139,000
4	Commercial	145,000
5	No Preheat (Residual)	148,000
5	Preheat (Residual)	149,000
6	Heavy (Residual)	152,000

6. Compute the Net Overall Value of the Energy by multiplying Total Energy Production from solar system by the Value of the Displaced Energy and dividing that value by the Boiler or Heater efficiency.
7. Estimate the allowable refurbishment budget in order for the system to pay for the repairs within ten years. Do this by multiplying the overall Value of the Energy from the solar system by ten. If you require a shorter payback, then multiply by the number of years desired instead of ten.

An Example Worksheet

Suppose a non-operating solar pool system is being considered for refurbishment at MCAS Yuma. The solar pool system includes 4,200 sq. feet of unglazed collector area, of which 3,900 sq. ft. is salvageable and will be put into service. The remainder will be bypassed and left unused. The panels are tilted up from the south about 30°, approximately equal to the latitude. The pool is used for five months of the year (May through September). The cost of the displaced fuel is \$5.29/MMBTU and the boiler currently in use at the pool is 21 years old. A payback of nine years is desired.

1. Since Yuma is not listed in the table, an appropriate site is substituted. Dagget, CA is a good substitute. The ADR is 2094.7 BTU/sf/day.
2. Based on the guidance in the text, this southern latitude site's ADR in summer is about 15% above the average, or about

$$1.15 \times 2094.7 \cong 2408.9 \text{ BTU/sf/day.}$$

The system will incorporate 3,900 sq. feet of collectors. Therefore, the total daily radiation on the collectors is

$$3900 \times 2408.9 = 9,394,710 \text{ BTU}$$

$$\text{or} \quad \cong 9.4 \text{ MMBTU}$$

The system operates for five months or 155 days. Therefore, the total radiation on the collectors is

$155 \times 9.4 \cong 1457$ MMBTU/operational season.

3. Since the pool is a summer operation, the assumed solar connection efficiency is 0.5 and the total energy production for the operational period is $0.5 \times 1457 = 728.5$ MMBTU
4. The value of the amount of displaced energy is \$5.29/MMBTU
5. The boiler is old, so an efficiency of 0.6 is used.
6. The net overall value of the energy is
 $(728.5 \text{ MMBTU} \times \$5.29 / \text{MMBTU}) / 0.6 = \$6,422.94$
7. Determine the refurbishment budget.
 $9 \text{ years} \times \$6,422.94/\text{yr} = 57,806.46$

This analysis indicated that up to \$57,806 can be expended on this refurbishment effort and obtain a payback in about nine years. Keeping in mind that this is a rough estimate, the energy manager uses the results conservatively.

APPENDIX F: LCCID

1. COMPONENT MARINE CORPS		FY 2000 MILITARY CONSTRUCTION PROJECT DATA		2. DATE 23 August 1999	
3. INSTALLATION AND LOCATION Marine Corps Base Twenty Nine Palms, AZ			4. PROJECT TITLE Solar Water Heating Refurbishment		
5. PROGRAM ELEMENT MCEMP	6. CATEGORY CODE 821-30	7. PROJECT NUMBER		8. PROJECT COST (\$000) \$45	
9. COST ESTIMATES					
ITEM		UM	QUANTITY	UNIT COST	COST (\$000)
Engineering Estimate		LS	1	45	
Commercial Expense (25% O&P)					
Contingency (5%)					
SIOH (8%)					
TOTAL CONSTRUCTION COST					
Design Fee (None, if design completed)					
Field Investigation (None, if design completed)					
TOTAL COST					
TOTAL DESIGN AND CONSTRUCTION COST					
10. DESCRIPTION OF PROPOSED CONSTRUCTION:					
This project will replace or rebuild non-operational parts of nine existing separate solar hot water heating systems. These will then become working systems supplying hot water.					
11. REQUIREMENT:					
<u>Project:</u> Will reduce energy consumption by ensuring that the solar systems are operating at an efficient level.					
<u>Requirement:</u> Executive Order 13123 set a goal of achieving at least a 35% energy reduction between FY85 and FY2010 at federal facilities. This project will aid MCB Twenty Nine Palms effort in obtaining that goal by reducing its annual electrical power and gas consumption by a total of 1,295 MMBTUs.					

1. COMPONENT Marine Corps	FY 1999 MILITARY CONSTRUCTION PROJECT DATA	2. DATE 14 Oct 99
3. INSTALLATION AND LOCATION MCB Twenty Nine Palms, AZ		
4. PROJECT TITLE		5. PROJECT NUMBER
<p>11. REQUIREMENT</p> <p><u>Current Situation:</u> A number of non-operational solar thermal systems exist at MCB 29 Palms. From examining these systems it has been concluded that these systems could be refurbished and brought back to an operational state. The candidate systems include a large barracks that contains 80 4' x 4' panels, as well as a number of smaller systems throughout the base. The number of square feet of solar panels planned for refurbishment is about 3500ft², of which 3,000 ft² is expected to be salvageable.</p> <p><u>Impact if Not Provided:</u> The systems will continue to sit where they are and slowly erode away. As more time passes more parts of each system will become unsalvageable, which will then cost more to bring each system to operate at peak efficiency. Experience has shown refurbishing existing solar systems does work. Six solar systems at MCB Camp Pendleton and three large barracks solar systems at MCB 29 Palms have been successfully refurbished.</p> <p><u>Additional:</u> This project provides a Savings-to Investment Ratio of 3.46 and a Simple Payback of 5 years.</p> <p><u>Project Site:</u> This project will be located at buildings xx66 (80 panels), 1439 (2 panels), 1815 (9 panels), 1933 (12 panels), and 1934 (6 panels).</p> <p><u>Economic Analysis:</u> See attached Life Cycle Cost Analysis Summary.</p> <p><u>Points of Contact:</u></p> <ul style="list-style-type: none"> a. Dick Walsh, HQMC, Code LFF-1, Energy Conservation Program Manager, (703) 695-9781 or 8385 b. Jim Gehrke, MCB 29 Palms c. Dave Menicucci, Sandia National Laboratories, (505) 844-3077 <p><u>Economic Alternatives Considered:</u></p> <ul style="list-style-type: none"> a. Continue burning natural gas to generate hot water. 		

NBSLCC program which is documented in SP 709. BLCC provides LCC computational support for private sector projects as well as for federal projects.

To order any of these publications and software products call:

Energy Efficiency and Renewable Energy Clearing House (800) DOE-EREC (800-363-3732)

or write or fax your order to:

U.S. Department of Energy
Federal Energy Management Program, EE-90
1000 Independence Avenue, S.W.
Washington, DC 20585-0121
Fax: (202) 586-3000

BLCC and related LCC software may also be purchased from the following vendors:

FlowSoft
5 Oak Forest Court
Saint Charles, MO 63303-6622
Voice: (314) 922-3569
Fax: (314)-441-7752

Enerav Information Services
P.O.-Box 381
St. Johnsbury, VT 05819-0381
(802) 748-5148

or downloaded via Internet from the FEMP home page at <http://www.eren.doe.gov/femp> (click on icon Technical Assistance and go to Analytical Software Tools).

Workshops on the life-cycle costing method and energy analysis are conducted at locations around the country each year. The workshops include training and software for BLCC and the associated programs QuickBLCC, DISCOUNT, EMISS and ERATES. A schedule of the workshops can be obtained through the FEMP help desk at 1-800-DOE-EREC (1-800-363-3732), or FAX 202-586-3000.

Three video training films in a series entitled "Least-Cost Energy Decisions for Buildings" have been prepared by NIST. These films include "Introduction to Life-Cycle Costing," "Uncertainty and Risk," and "Choosing Economic Evaluation Methods." The video films and companion workbooks can be ordered from Video Transfer, Inc., 5709-B Arundel Avenue, Rockville, MD 20852, Telephone (301) 881-0270, Fax (301) 770-913 1.

Further information on the Federal Energy Management Program can be obtained from the Federal Energy Management Program Staff, Office of the Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy. Please direct communication to: FEMP, EE 90, U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, DC 20585.

 * N I S T B L C C : C O M P A R A T I V E E C O N O M I C A N A L Y S I S (v e r . 4 . 7 0 - 9 9) *

Project: Solar Panel hot water
 Base Case: Press Hotwat
 Alternative: Solar Panels

Principal Study Parameters:

 Analysis Type: Federal Analysis--Energy Conservation Projects
 Study Period: 20.00 Years (DEC 1999 through NOV 2019)
 Plan/Constr. Period: 0.50 Years (DEC 1999 through MAY 2000)
 Service Period: 19.50 Years (JUN 2000 through NOV 2019)
 Discount Rate: 3.1% Real (exclusive of general inflation)
 Base Case LCC File: 29PALMFUEL.LCC
 Alternative LCC File: 29PALMSOLR.LCC

Comparison of Present-Value Costs

	Base Case: Press Hotwat	Alternative: Solar Panels	Savings from Alt.
Initial Investment item(s):			
Capital Requirements as of Serv. Date	\$0	\$44,318	-\$44,318
Subtotal	\$0	\$44,318	-\$44,318
Future Cost Items:			
Annual and Non-An. Recurring Costs	\$7,490	\$8,034	-\$544
Energy-related Costs	\$145,492	\$2	\$145,490
Residual Value at End of Study	\$0	-\$2,444	\$2,444
Subtotal	\$152,982	\$5,593	\$147,390
Total P.V. Life-Cycle Cost	\$152,982	\$49,911	\$103,071

Net Savings from Alternative 'Solar Panels' compared to Base Case 'Press Hotwat'

Net Savings	=	P.V. of Non-Investment Savings	\$144,946
	-	Increased Total Investment	\$41,875
		Net savings:	\$103,071

Note: the SIR and AIRR computations include differential initial costs, capital replacement costs, and residual value (if any) as investment costs, per NIST Handbook 135 (Federal and MILCON analyses only).

Savings-to-Investment Ratio (SIR)

For Alternative 'Solar Panels' compared to Base Case 'Press Hotwat'

SIR	=	P.V. of non-investment savings		=	3.46
		Increased total investment			

Adjusted Internal Rate of Return (AIRR)

For Alternative 'Solar Panels' compared to Base Case 'Press Hotwat'

(Reinvestment Rate = 3.10%; Study Period = 20 years)

AIRR = 9.70%

Estimated Years to Payback (from beginning of Service Period)

Simple Payback occurs in year 5

Discounted Payback occurs in year 5

ENERGY SAVINGS SUMMARY

Energy type	Units	---- Average Annual Consumption ----			Life-Cycle Savings
		Base Case	Alternative	Savings	
Natural Gas	MBtu	1,295.0	0.0	1,295.0	25,252.5
Other	MBtu	0.0	1,295.0	-1,295.0	-25,252.5

APPENDIX G: MANUFACTURER'S LIST OF BTU METERS (8/2000)

1. Controlotron Corp.
2. Onicon Inc.
3. ISTECH Corp.
4. Omega Engineering, Inc.
5. MSC Industrial Supply Co.
6. Texmate Inc.
7. Controls Warehouse
8. Sponsler Co., Inc.
9. Non-Linear Systems
10. Material Control, Inc.
11. Precision Digital Corp.
12. Infrared Services, Inc.
13. Bright Technology LLC
14. Cal Research, Inc.
15. Mitchell Instrument Co.
16. Keegan Electronics Inc.
17. Solar Miser

Appendix H: Example of O&M Manual

Solar Pool Heating Systems at MCB Camp Pendleton

Operation & Maintenance Manual

Sandia National Laboratories

Mike Walsh
Mike Walsh Enterprises

Earl Rush
Solar Thermal Test Department
Sandia National Laboratories
Lead Engineer

David Menicucci
Renewable Energy Office
Sandia National Laboratories
Project Manager

CONTENTS

CHAPTER 1. GENERAL INFORMATION	H-6
1.1 INTRODUCTION.	H-6
1.2 PRIMARY COMPONENTS.	H-5
1.2.1 Solar Circulating Pumps and Associated Piping.	H-5
1.2.2 Solar Arrays.	H-10
1.2.3 Electrical Specifications.	H-12
1.2.4 Solar Control Panel – Components.	H-15
1.2.5 BTU/Flow Meters.....	H-21
1.3 THEORY OF OPERATION.....	H-23
1.3.1 Control Logic.....	H-23
CHAPTER 2. PROCEDURES.....	H-29
CHAPTER 3. ROUTINE MAINTENANCE REQUIREMENTS.....	H-31
3.1 SOLAR CIRCULATING PUMPS AND ASSOCIATED PIPING.....	H-31
3.1.1 Electric Motor-Driven Pumps	H-33
3.2 SOLAR ARRAYS.	H-34
3.3 THE SOLAR CONTROL PANEL.....	H-34
3.3.1 Vacuum Relief Valves.....	H-35
3.3.2 Time Delay Relays.	H-36
3.3.3 Pumps.	H-36
3.4 BTU METERS.....	H-36
3.4.1 Thermocouples.	H-36
3.5 REPLACEMENT PARTS.....	H-36
CHAPTER 4. TROUBLESHOOTING.....	H-37
4.1 TROUBLESHOOTING ELECTRIC MOTOR-DRIVEN PUMPS.....	H-37
4.2 TROUBLESHOOTING THE FAILSAFE VALVES	H-39
4.3 TROUBLESHOOTING TIME DELAY RELAYS.....	H-39
4.4 TROUBLESHOOTING TEMPERATURE DISPLAY FOR GL CONTROLS	H-39

List of Figures

1. Solar Pump.	H-6
2. Solar Array.	H-6
3. Control Systems.....	H-7
4. Isolating Valves.....	H-8
5. Base Mounted Pump.....	H-9
6. Rack Holding the Solar Collectors.....	H-11
7. Copper Drain Line Coming Out of the Solar Loop and going along the Floor to the Filter Pump.	H-12
8. Copper Drain Line Connected to Filter Pump through the Blue Watson McDaniel Float Trap.	H-13
9. Array Piping Supply/Return Lines.	H-14
10. Motor Starter.....	H-15
11. Inside of Control Box.	H-16
13. Vacuum Relief and Air Eliminator Valves.....	H-19
14. Close-up of Vacuum Relief and Air Eliminator Valves.....	H-19
15. The FP-93 BTU Meter.....	H-22
16. Sandia's BTU Meter.....	H-22
17. Temperature Sensors for FP-93.....	H-24
18. Orifice Plate for FP-93.	H-25
19. Time-Delay Relay in the Control Box.....	H-27
20. Fossil-fired Backup Pool Heater.....	H-28
21. Pool Filters.....	H-31
22. Pool Filter Controls.	H-32
23. Pool Filter Warning Signs.	H-33

CHAPTER 1. GENERAL INFORMATION

1.1 INTRODUCTION.

This manual is intended to describe how the solar training tank systems at Camp Pendleton are intended to be operated. Technical details are provided to allow system checkout, operation, and maintenance. The map of locations of solar panel systems is in Appendix A.

1.2 PRIMARY COMPONENTS.

The solar pool heating system comprises four major components: a circulator pump (see Figure 1), a solar array with its associated piping (Figure 2), an automatic control system (Figure 3), and isolation valves with actuators (Figure 4). A brief description of each component and its respective function follows.

1.2.1 Solar Circulating Pumps and Associated Piping.

The solar circulator is actually a circulating pump requiring the net positive suction head of the filter system to be online for it to provide adequate flow through the solar arrays (see Figure 1). These pumps are located on pedestals within the filter equipment rooms. They are installed with motor starters having all appropriate disconnect and overload protections. Typically they are 5 h.p. rated, with the one exception being the unit installed at the Area 14 pool, which is 10 h.p. When the solar system is active, the solar circulator receives suction flow from the filter system flow and sends water to the arrays. Piping in the filter house and underground is PVC; at the solar arrays a transition to copper is made for all aboveground piping. The pumps are started with a control signal from the differential thermostat controller.

Each system has been provided with a new 5 h.p. circulating pump (exception: there is a 10 h.p. unit located at Area 14). These pumps have been installed on new pump pads with proper anchors. They are bronze fitted, centrifugal pumps, which provide flow through the solar arrays, based on the dictates of the differential thermostat. Each is equipped with a gauge allowing for pressure readings at both the pump suction and discharge piping. The suction and discharge lines are 6 in., reducing as required at the pump's suction and discharge ports, and both are equipped with vibration isolators. Flow to the suction side of the pump originates at a tee located in the 10 in. filter discharge line. This solar supply interconnect is upstream of an adjacent tee, which is the interconnect for the solar return piping. Both tees are located

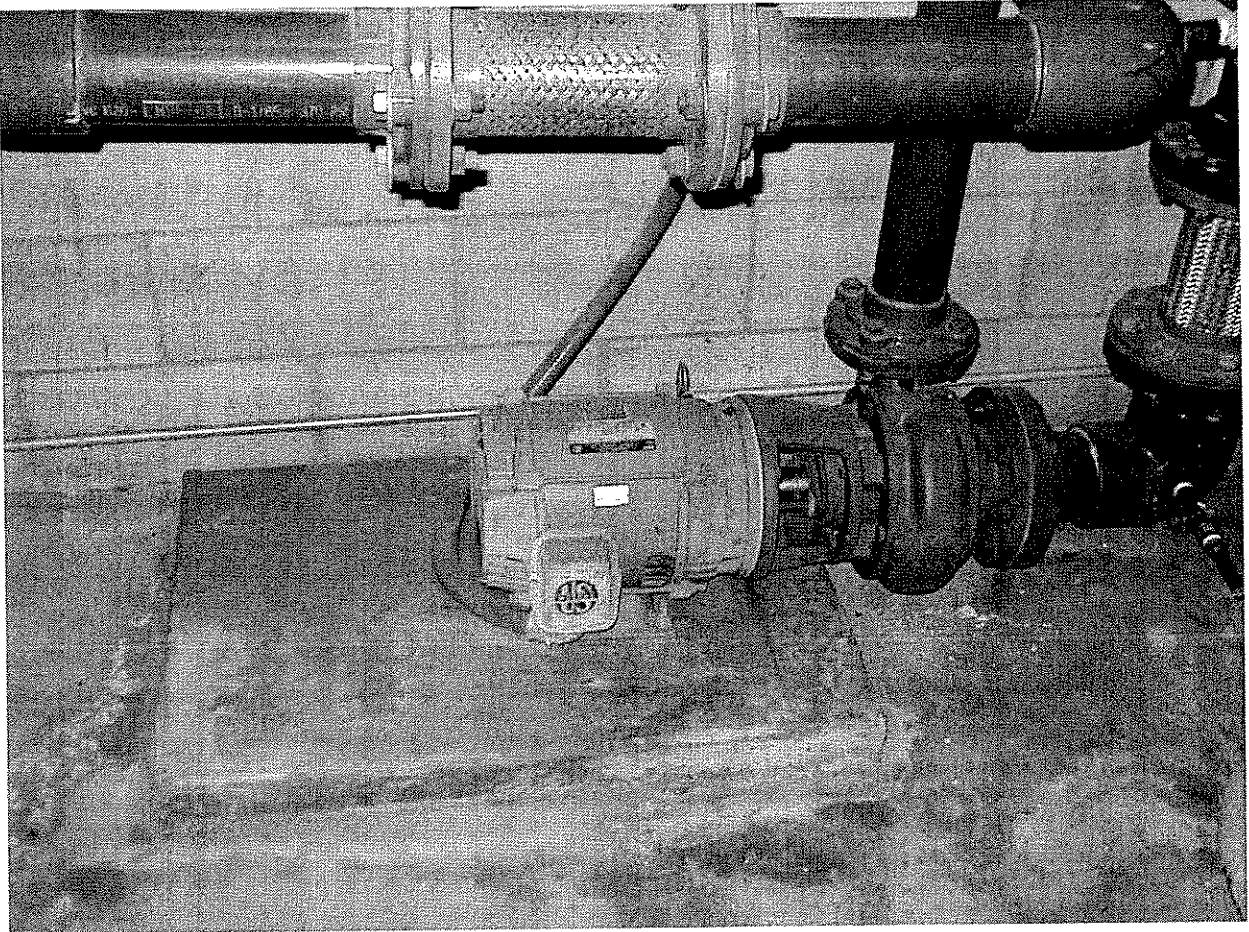


Figure 1. Solar Pump.

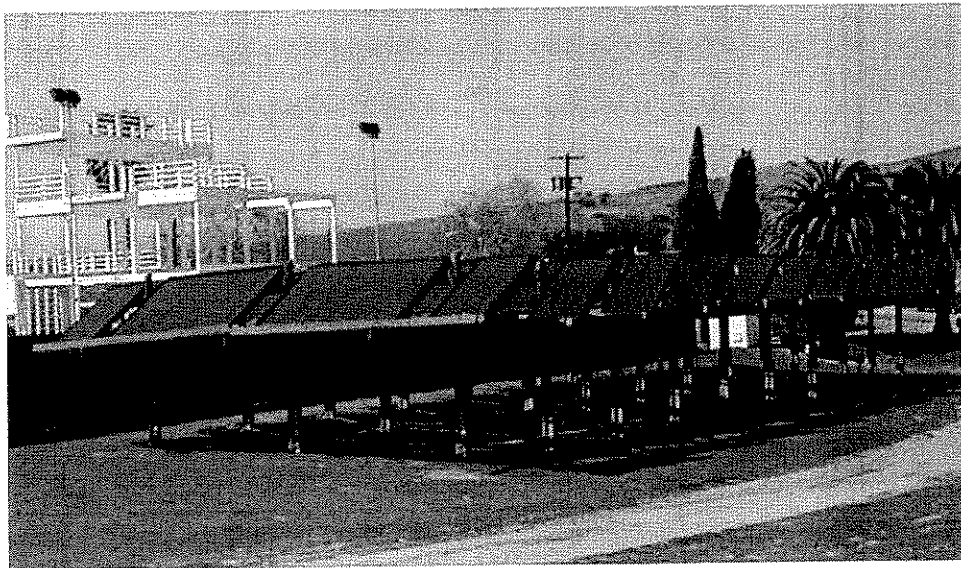


Figure 2. Solar Array.

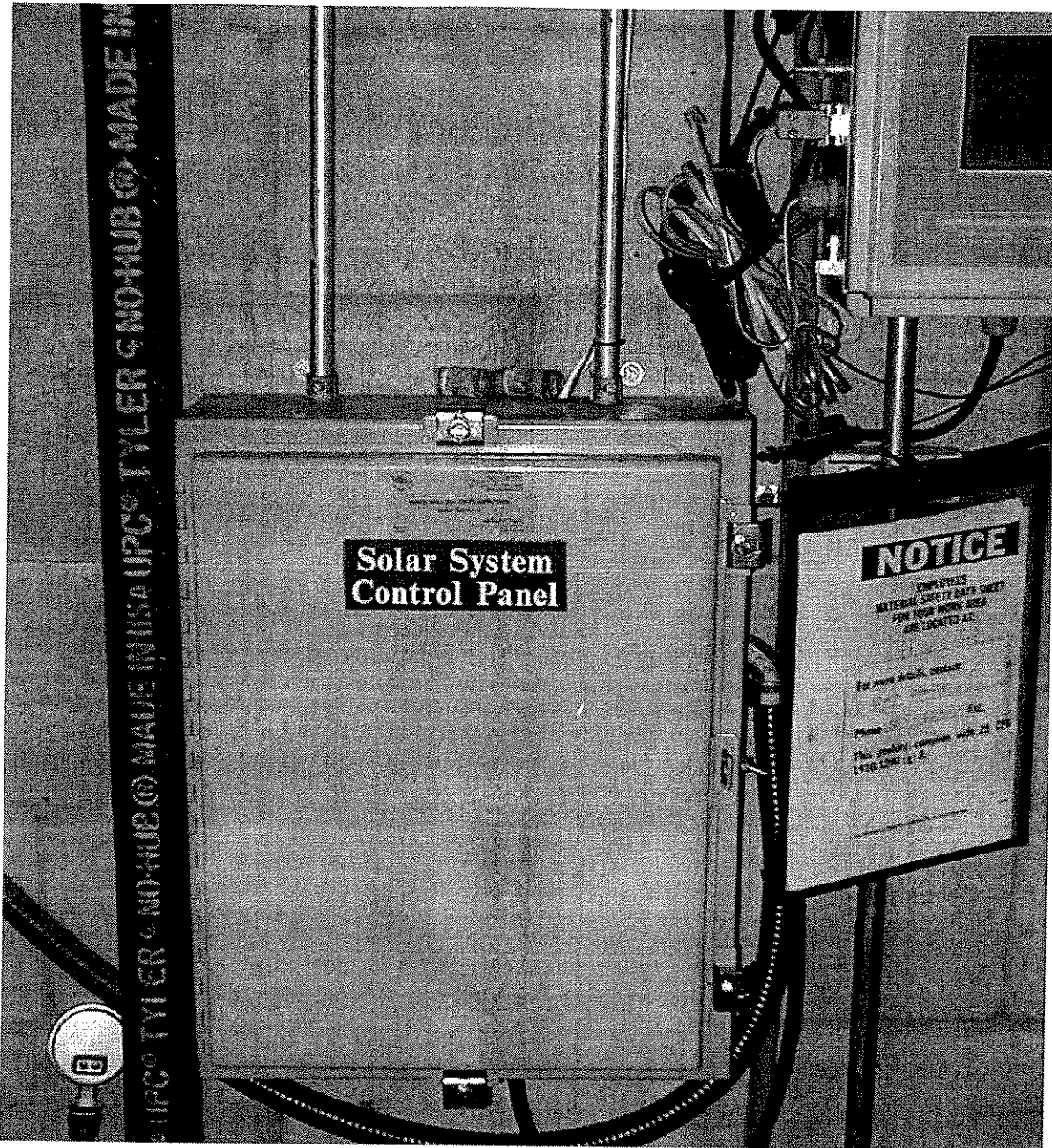


Figure 3. Control Systems.

downstream of the system filter bank and upstream of the steam heat exchanger or, in the case of the new facilities, the gas boiler. The solar supply line heads underground after discharge from the pump and travels to the array in schedule 80 PVC, where it transitions to copper (as noted above). The return line travels adjacent to it and ties back into the filter line (as noted above). Both lines, near the point where they connect to the filter line, are equipped with 4 in. butterfly valves, which in turn are equipped with electrically driven actuators.

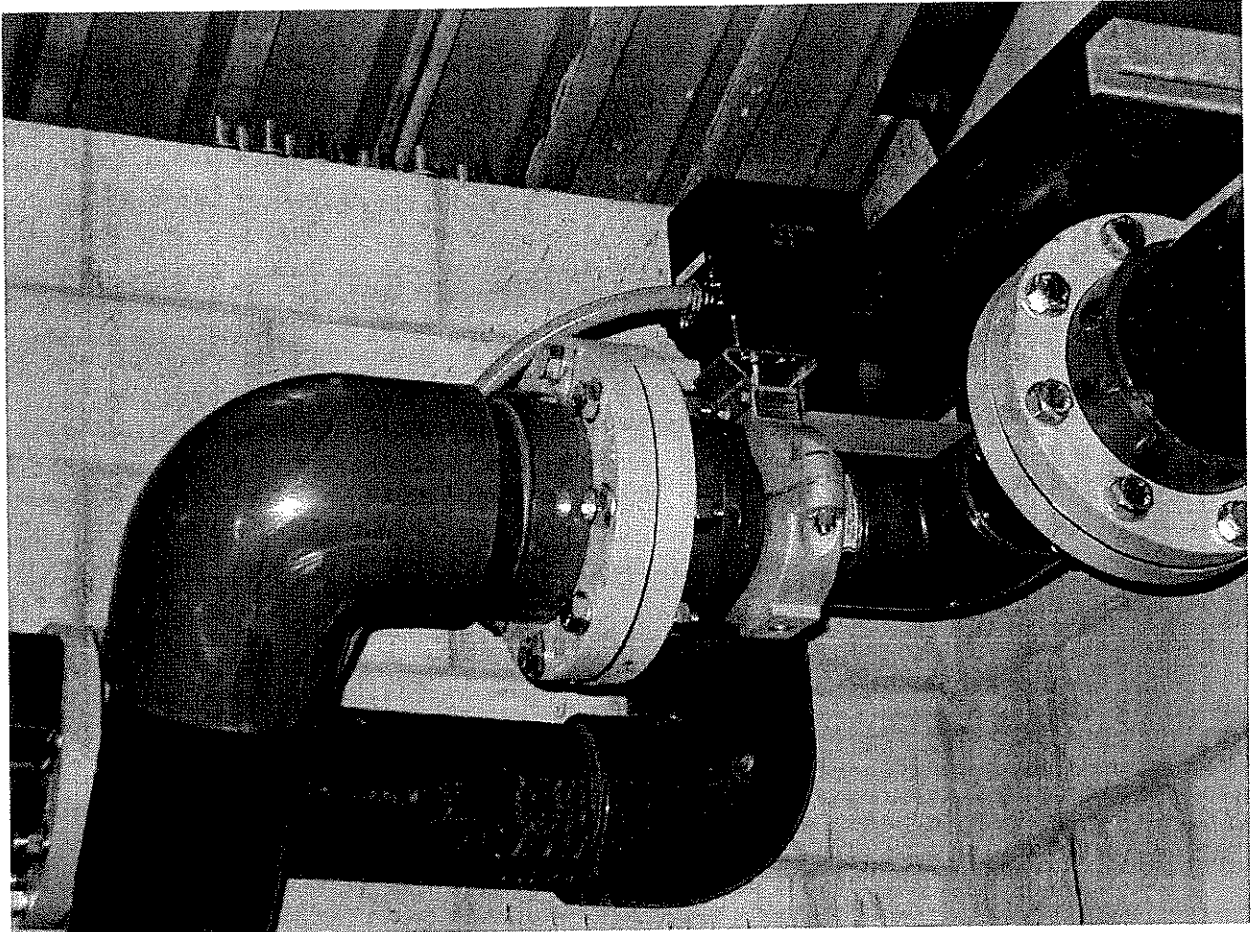


Figure 4. Isolating Valves.

The main pump in the solar panel system is an electric water-drawn pump (see Figure 5). It is used to circulate pool water through the collector array.

1.2.1.1 Electric Motor-Driven Pumps

Operation

Prime the pump before the initial start up by filling the casing with liquid through the top fill plug, the discharge port, or by installing a pipe tee at the discharge of the pump. When installing a tee, use the horizontal leg of the tee as the pump discharge and place a pipe plug in the vertical leg. This procedure will help facilitate priming later.

1.2.1.2 Centrifugal Pumps

Operation

These centrifugal pumps circulate pool water through the array, based on the output of the differential thermostat and the position of the isolation valves. Because of an interlock with the

PREPARED BY:	SANDIA NATIONAL LABORATORIES FACILITIES ENGINEERING	SKETCH NO.:	15J-32CP
CHECKED BY:		SCALE:	NONE
DATE:	REV:	BASE MOUNTED PUMP	
9-14-93		MECHANICAL STDPIP.DGN	

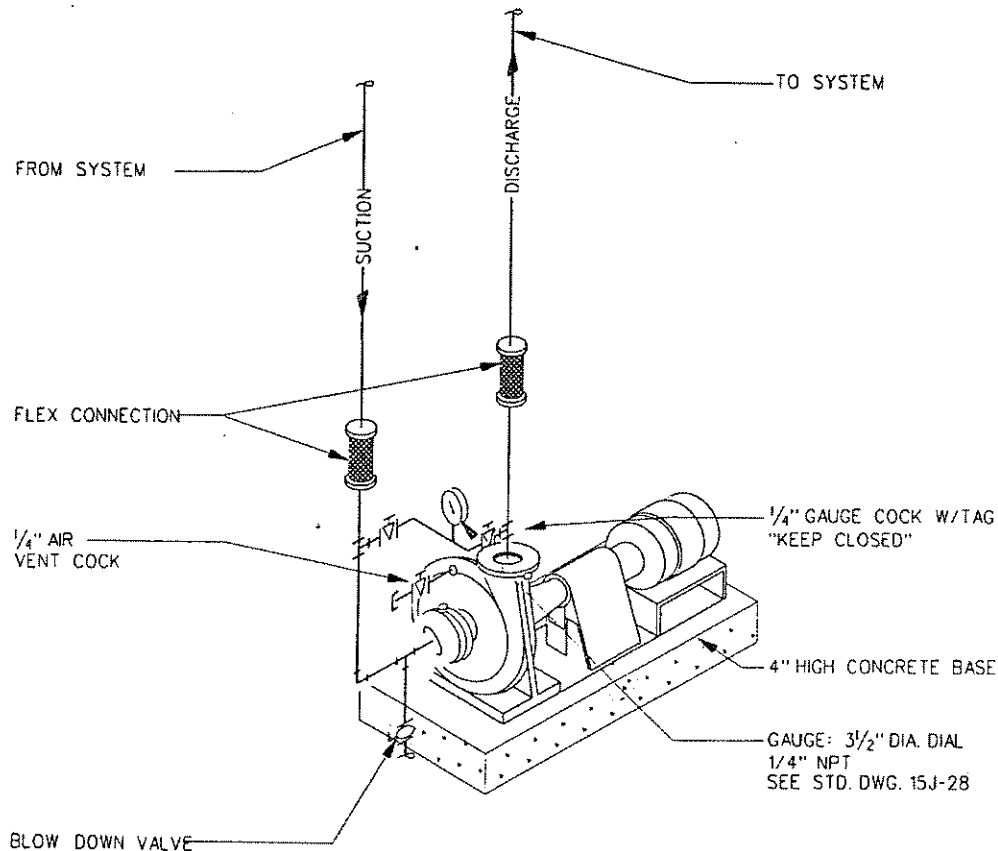


Figure 5. Base Mounted Pump

filter pump, these pumps do not operate unless the filter pump is online and, therefore, always have a minimum net positive suction head of fifteen pounds-per-sq.-in.-gauge (15 psig), thus eliminating the need for priming.

Important: Power should be applied momentarily to the pump at first and the direction of rotation checked. When viewing the rear of the motor (opposite the pump end), the motor shaft should be rotating clockwise. If it is not, disconnect power and recheck wiring to motor. (See product sheet.)

Note: Never shut off discharge or restrict suction flow while the pump is operating.

1.2.2 Solar Arrays.

The solar array is composed of a varying number of 4 ft × 8 ft copper solar collectors, with the exception of new synthetic units at the Area 14 pool. The collectors are mounted on a rack of post-and-beam construction, with a southern orientation (see Figure 6). With the exception of the new units at the Area 14 pool, these collectors are 15 to 20 years old. The hydronic flow pattern is from the solar pump, to the array's piping, where "supply" flow is manifolded into the bottom header of each collector, flowing up and out through the top header. "Return" flow is collected in a reverse-return pattern and flow is then directed back to the existing filter piping in the pump house. The flow in all cases originates from the filter system, after the filters and before the boiler or heat exchanger. Arrays are equipped with combinations of air vents and vacuum breakers. Valves are available for isolating each sub-array from the rest of the system, although some have been found to be inoperative.

Note: Incorporated into each system's piping is a "drain line" that is intended to draw the water out of the arrays when the solar system shuts down. Upon the closing of the butterfly valves and shutdown of the solar circulator, the water trapped in the solar arrays is drained by a 3/4 in. copper line that originates at or near the solar circulator but downstream from the supply line isolation valve (Figure 7). It terminates at the suction side of the filtration pump. The pump suction draws the water out of the array and back into the normal filtration system flow, which is typically running around the clock. The drain exists for three reasons: First, should water be trapped in the system on a warm summer day, it is possible for it to heat, expand, and cause damage to the solar collectors and couplings. Second, even in the very temperate conditions of MCB Camp Pendleton, it is possible for the water in a solar system array to freeze, with resultant damage to collectors and piping. Third, should the system shut down with freshly treated pool water (it can be either very strong base or acid) this drain line will eliminate any aggressive action by water on the metal collector surfaces. Air is prevented from entering the suction side of the filter pump (upon removal of the water from the array) by the presence of a Watson McDaniel float trap (see Figure 8). Should cleaning or repair of the trap be required, ball valves are located at each point of intrusion into the piping system for maintenance.

Each system has a field of solar absorber plates ("collectors") mounted on above-ground post-and-beam structures ("array"). These wood structures and the solar collectors have been in place for approximately 20 years. For most or all of that time, these systems, for a variety of reasons,

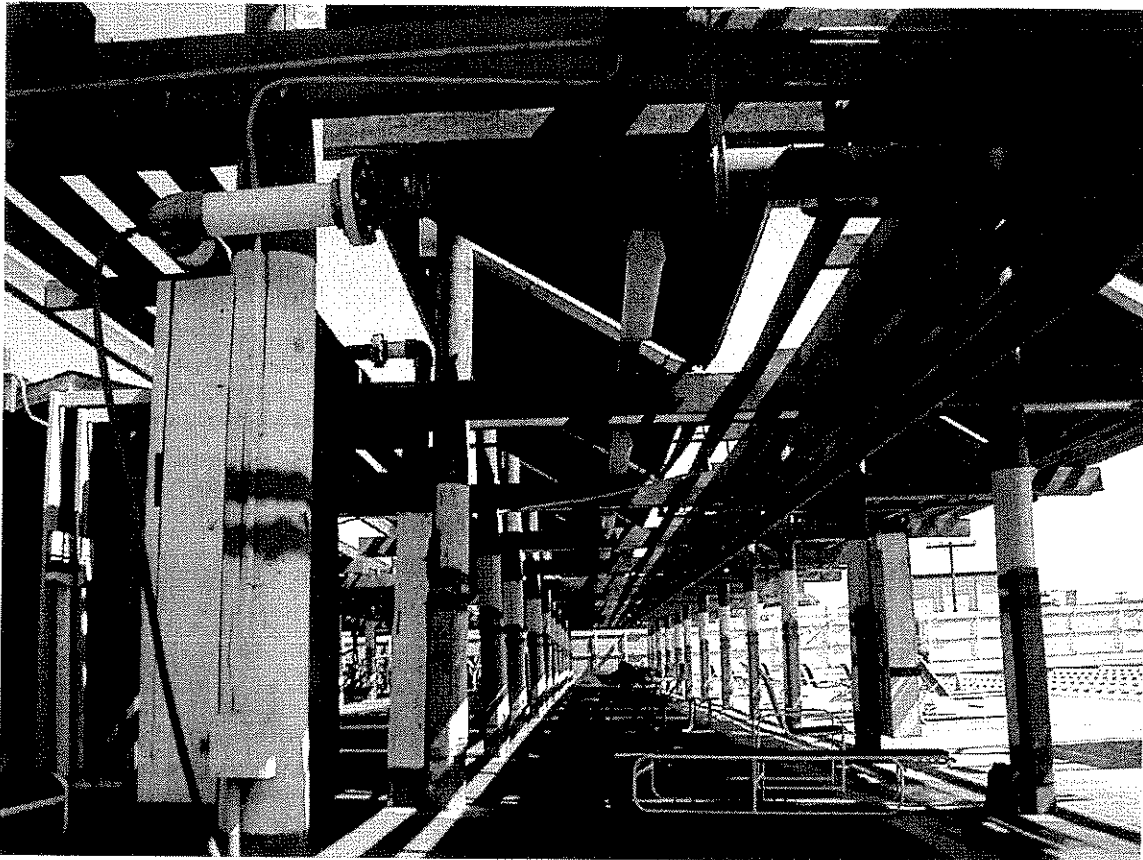


Figure 6. Rack Holding the Solar Collectors.

have been inoperative. The collectors are all copper in construction, with 1.5 in. headers, and are nominally 4 ft \times 10 ft in dimension. Collectors are joined to each other via a steel-jacketed expansion joint, brazed at both ends to the adjoining collectors. As these couplings have failed, they have been replaced with mission-style couplings, comprised of an inner sleeve of EPDM and an outer stainless steel jacket.

Array piping consists of 6 in. supply and return mains (see Figure 9). These mains are primarily copper, with a copper/PVC flanged transition connection just prior to and just after the point where they head underground. Off these mains, flow is manifolded through subarrays. Line sizes increase and decrease per flow requirements in the manifolding process. At the exit point of each array are a vacuum breaker and an air vent. The air vents assist in removing air from the arrays on startup, while the vacuum breakers allow for the system to drain back to the pools. With the isolation valves closed, all water can be removed from the solar array via the previously noted 3/4 in. drain line operating in conjunction with the site's filter pump system. The array will trickle down even when the filter pump is off.

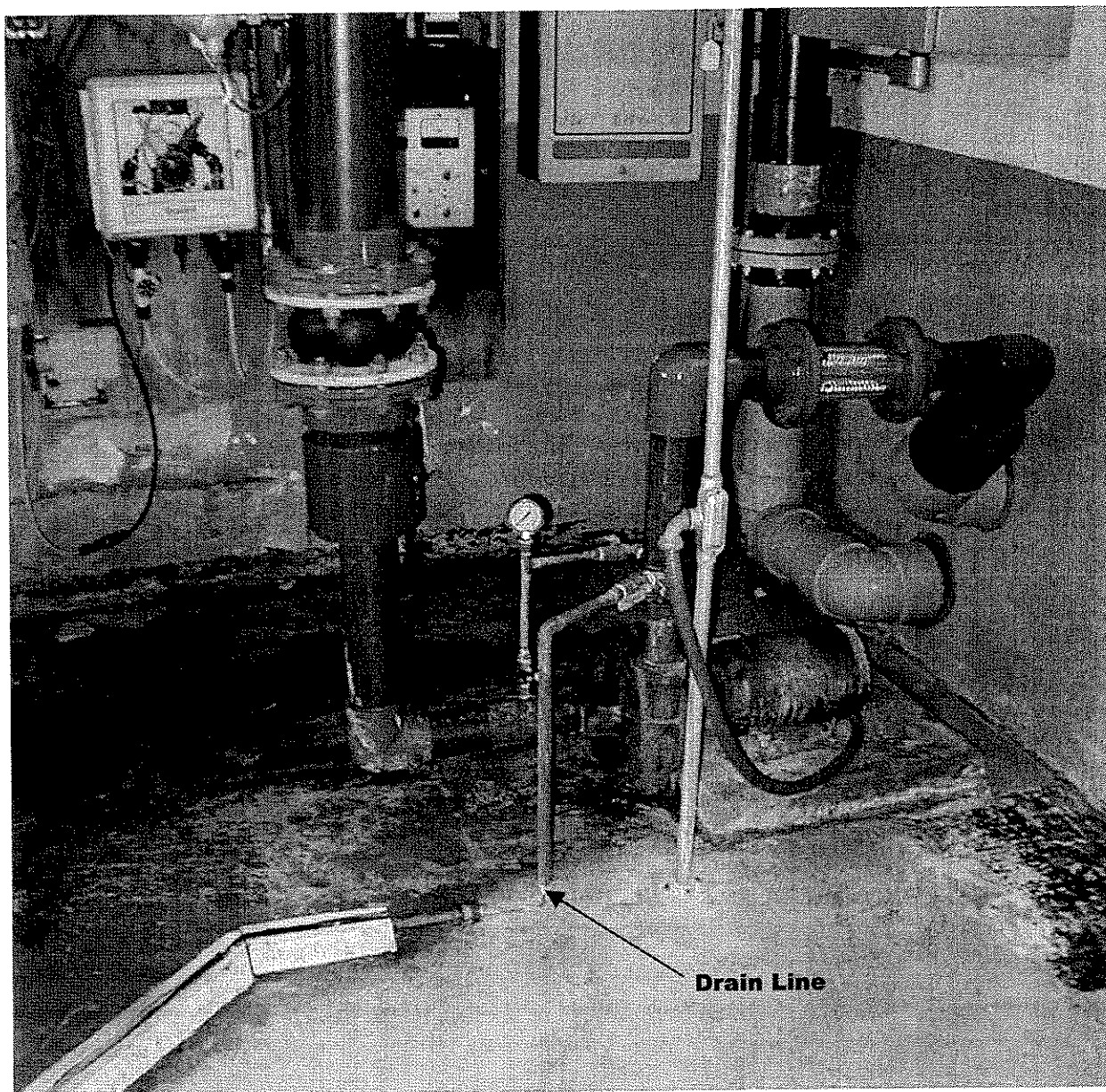


Figure 7. Copper Drain Line Coming Out of the Solar Loop and going along the Floor to the Filter Pump.

1.2.3 Electrical Specifications.

Each pump is wired through its own motor starter (see Figure 10), located either adjacent to the solar control panel or the existing motor starter for the filter pump. Service is either 230 VAC or 460 VAC—it varies from site to site—and in all cases is three-phase. All motor starters are equipped with a service disconnect, which should always be pulled prior to servicing any portion of the system. The solar control is through the “hand” position of the motor starter.

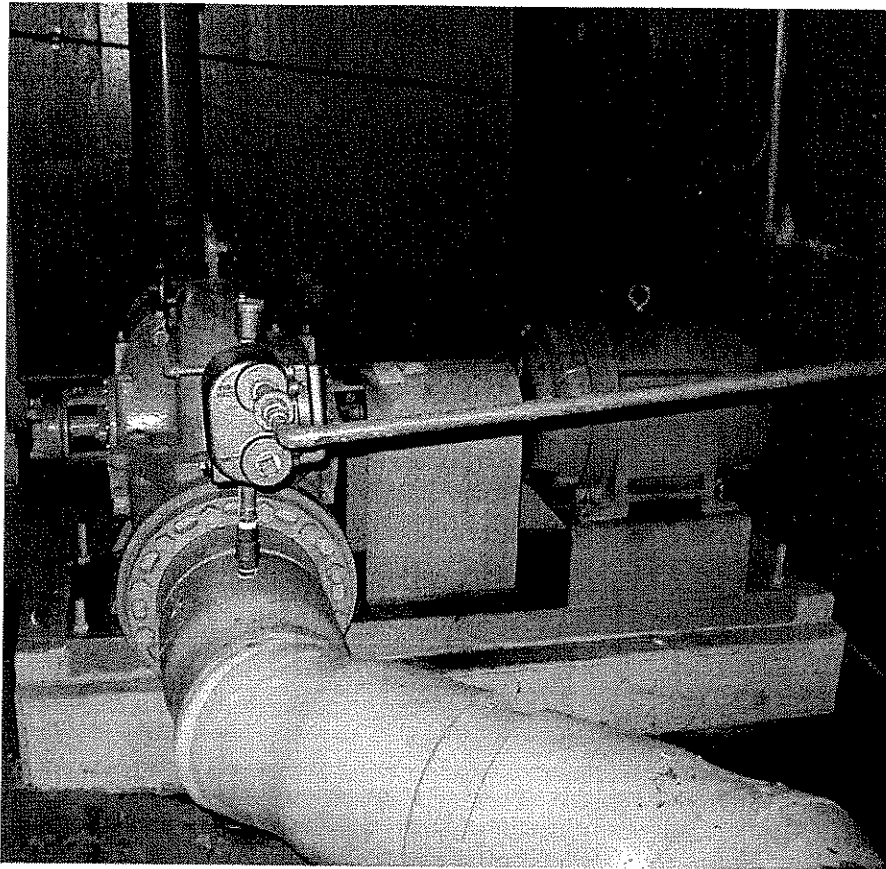


Figure 8. Copper Drain Line Connected to Filter Pump through the Blue Watson McDaniel Float Trap.

The valve actuators are wired for 115 VAC with minimal amp draws. They are driven both directions by the actuator motor; that is, they are double-acting, requiring an electrical signal to drive them into either the open or closed positions. Travel in the actuators is controlled by a set of movable cam lobes on the actuator's drive shaft.

The solar control panel requires an independent 115-VAC signal to power the actuator valves. All high-voltage wiring is located either in rigid metal or flexible, weather-tight conduit.

1.2.3.1 Butterfly Valve

The valves are 4 in. butterfly-type installed in both the supply and return lines of the solar loop. They are actuated by the solar differential controller through a relay. The valves are designed for failsafe operation. They are wired to close under battery power when grid electrical power is turned off (i.e., a power failure). This operation will ensure that the solar arrays never have water in them during a freezing period when power could fail.

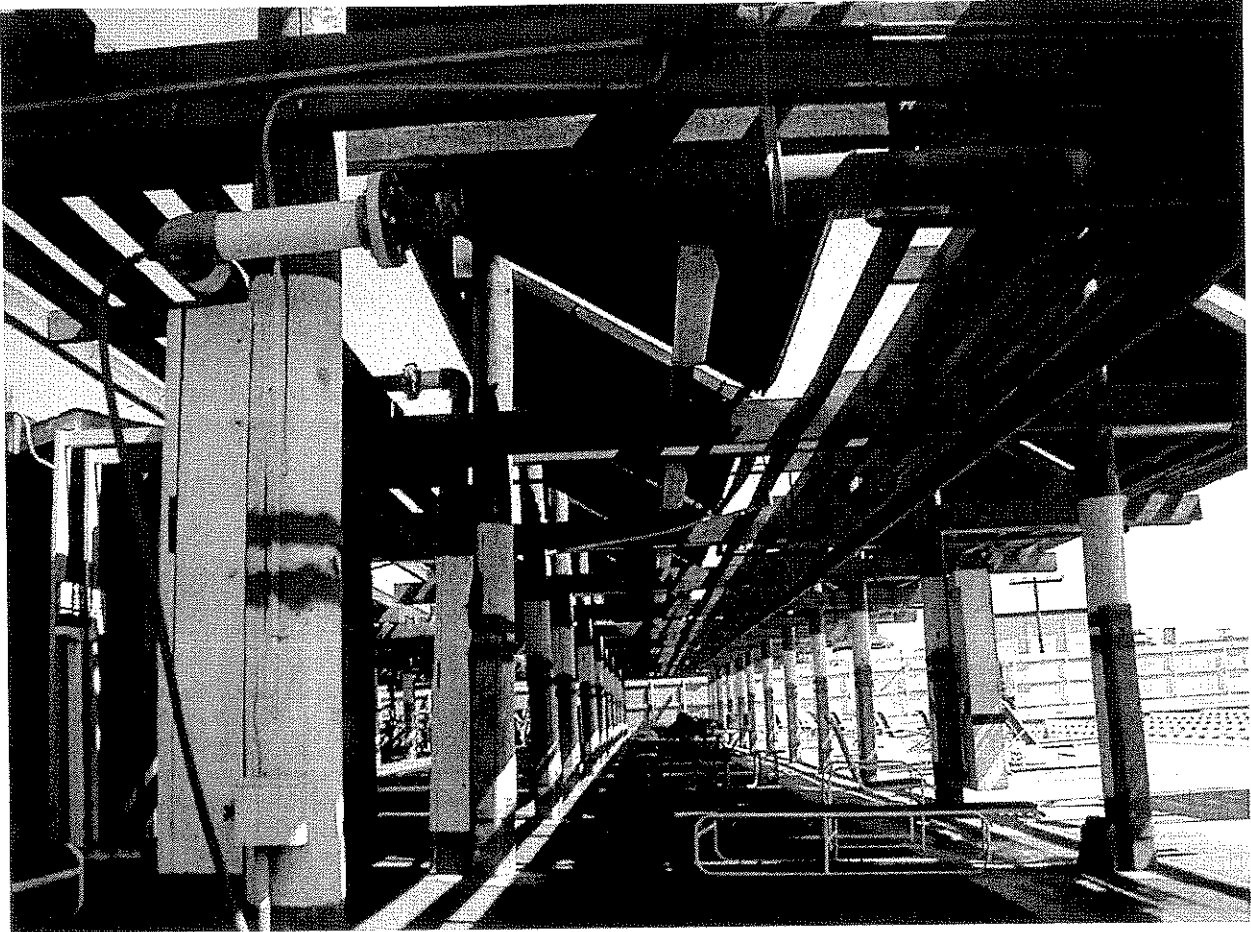


Figure 9. Array Piping Supply/Return Lines.

Each valve has a control box nearby with indicator lights that indicate their state of operation. The signal lighting system on the valve controls indicates the state of the failsafe valve controls (these valves will close upon loss of grid utility power). A green light only means that the grid power is being supplied to the valves and that the valves are open. A green light *and* a red light means that grid power is supplied to the valves and the valves are closed. A red light only means that grid utility power is not supplied to the valves and that the valves are closed.

1.2.3.2 PF-Series Electrical Actuators

Operation.

Pull the black “declutching knob” (PF-400, 700, and 1100) all the way up and hold (see product sheet in Appendix C). Apply a 5/8” open end wrench to the exposed shaft flats and rotate within the normal operating rotation or the actuator as indicated by the arrows. Push handwheel down (PF-2000) and rotate. Caution: There are several situations that could cause the thermal overload circuit to open. These situations should be resolved immediately.

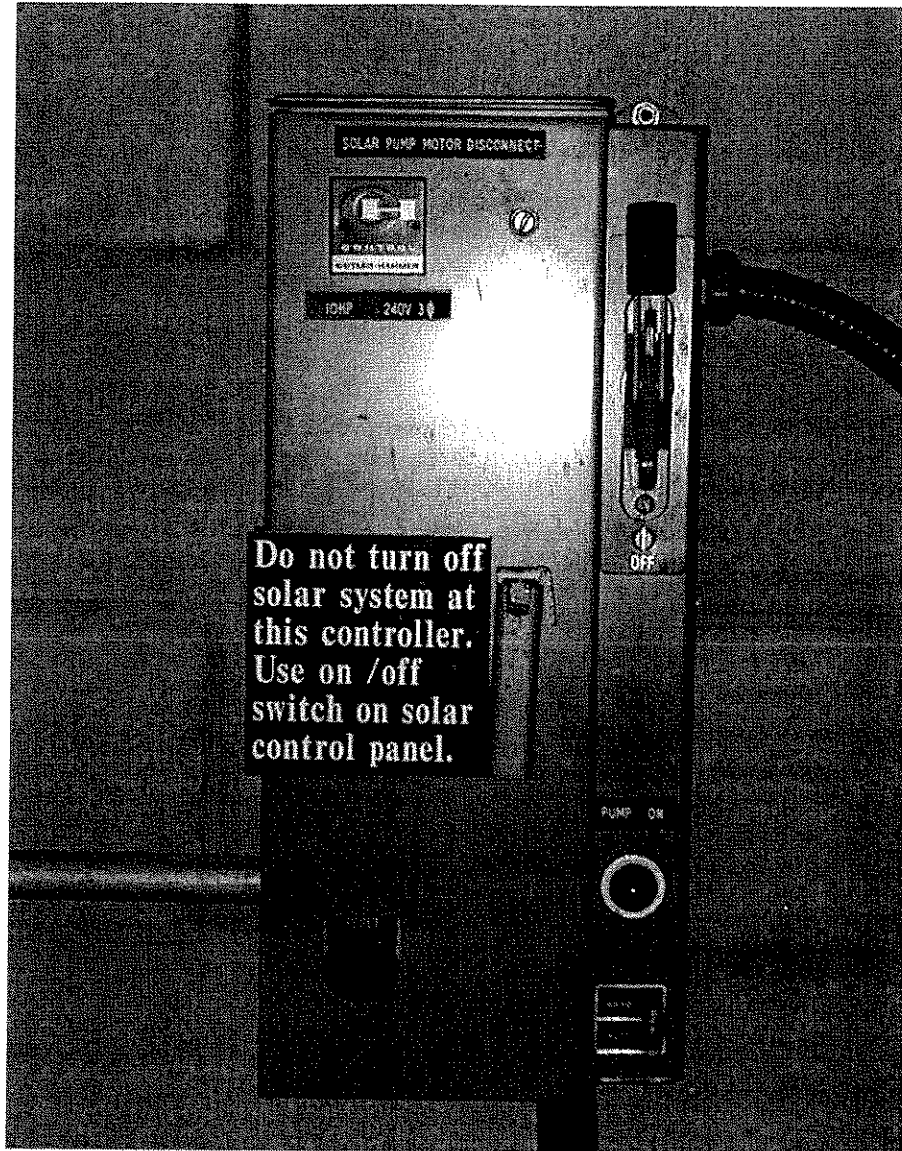


Figure 10. Motor Starter.

1.2.4 Solar Control Panel – Components.

The control panel (see Figure 11) contains a differential thermostat and various relays. The differential thermostat, commonly referred to as the “Delta-T” controller (see Figure 12), receives temperature inputs from two locations. One is a sun-sensor located on the roof of each filter room; the second is found in the normal filter system piping. The first provides the controller with a solar “potential” reading (“Is it hot enough to heat the pool?”), and the second provides a reading on the pool temperature (“Does the pool call for additional heating?”). In short, when the answer to both is “yes,” the Delta-T controller goes into “solar collection mode.” It is important to note that the Delta-T controller is energized by an interlock with the pool filter

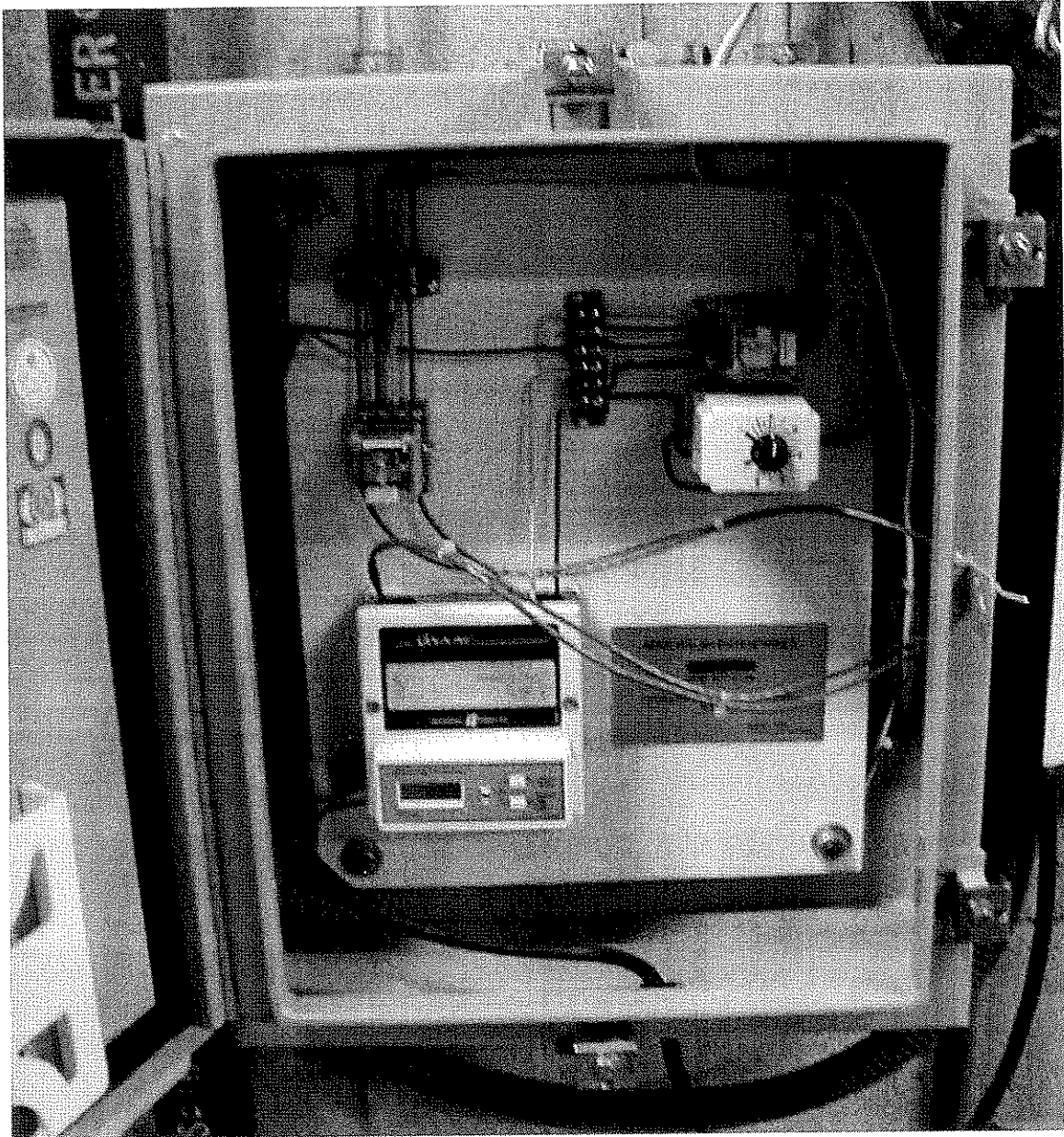


Figure 11. Inside of Control Box.

pump. If the filter pump is not on, there is no power to the Delta-T controller and the solar circulator pump cannot then run “dry.” That is, without water flow in the filter system, it is most probable that the solar circulator will cavitate and quickly suffer major damage. This interlock prevents that occurrence. When the Delta-T is in solar collection mode, it energizes first the isolation valves; then, after a several-minute time delay (allowing the valves to fully open and establish flow in the suction line), it energizes the solar circulator, resulting in flow through the solar array. When either there is inadequate solar energy available (e.g., hours of darkness, or



Figure 12. Delta-T Controller.

particularly windy/cool days) or the pool temperature has reached the preset temperature (this is set as a high-limit in the Delta-T controller) the system will shut down the solar circulator and close the isolation valves.

Each system contains two 4 in. valves, with one each located on the solar “supply” (flow to the array) and “return” (flow from the array) lines. These valves are modulated open and closed with attached valve actuators. Their purpose is to isolate flow to the solar array when the system is not in solar collection mode. They also allow the drain line to effectively remove the trapped water from the array in no-solar-flow situations.

The solar control panel is a NEMA 4 enclosure containing the following components:

- differential thermostat equipped with a digital temperature display. Other capabilities include a high temperature limit, variable “on” differential setting (“off” is fixed at 4°F) and a recirculation program for freeze protection
- “filter pump ON” relay
- solar circulating pump “motor starter ON” time delay relay
- valve actuator “open or closed” relay

Ancillary to the control panel are two solar sensors:

- 10 K ohm, blackbody “simulator” sensor, mounted at a rooftop location. No provisions were made in the original installation for a sensor loop to/from the solar array. This simulator, located with the same pitch and orientation of the array, is the best compromise available. This is the “collector” temperature input to the controller.
- 10 K ohm, temperature sensor located in the filter line, just prior to the solar supply line interconnect. This supplies the “storage,” or pool water temperature, to the controller.

These sensors are connected to the differential thermostat’s “sensor” terminals.

1.2.4.1 Vacuum Relief Valves and Air Eliminator Valves on the Solar Array

The vacuum and air valves are piped in parallel and are located on top of the array in various locations. The vacuum valves are used to break the vacuum allowing the solar array to drain when needed (see Figure 13). The air eliminators allow air to escape from the top of the array when the array is being filled with water (see Figure 14).

1.2.4.2 Time Delay Relays in Control Panel

The time delay relays combine solid-state digital timing circuits with an electromechanical relay for control of loads. In this instance, the time delay is used to allow time for the solar piping to charge with water before the solar pump is allowed to circulate. As stated elsewhere, this is to prevent the pump from running dry and being damaged by same. Relays in these units can handle up to 300 watts at 120 VAC. The time delay relays are UL Recognized (E40944) and CSA Certified (15734).

Operation of Pumps

Operation performed through time delay relay when controller senses sufficient solar radiation to operate. Refer to schematic for operational details.

1.2.4.3 Temperature Display for GL Controls

The TD-GL is a digital temperature display module for Independent Energy “GL” series of temperature controls. Temperature is displayed in °F or °C. The TD-GL continuously displays the collector sensor temperature and the storage temperature can be displayed by pushing and holding the upper button.

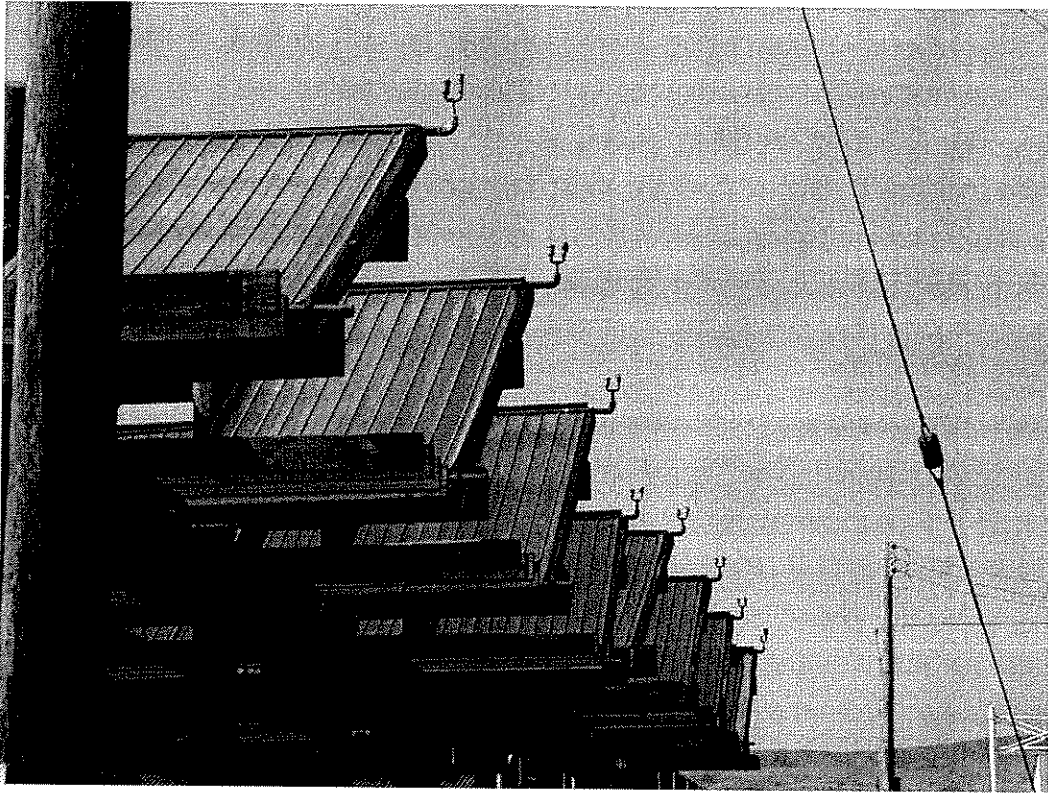


Figure 13. Vacuum Relief and Air Eliminator Valves.

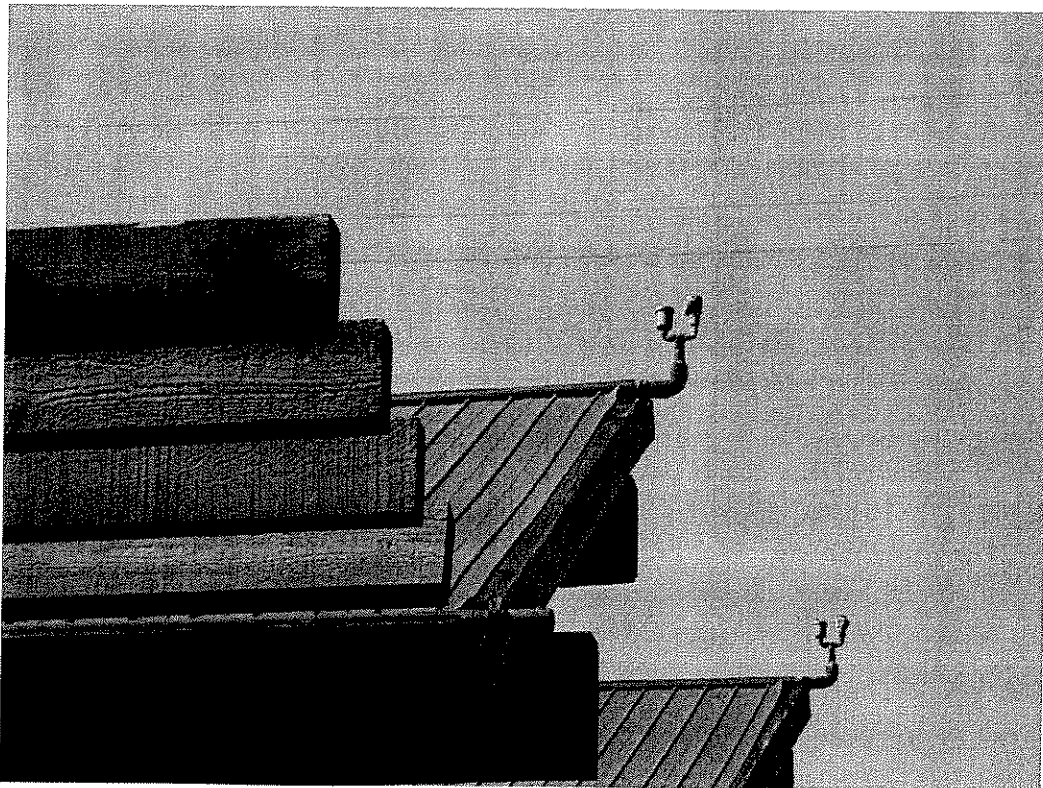


Figure 14. Close-up of Vacuum Relief and Air Eliminator Valves.

The TD-GL also stores in memory the highest and lowest collector sensor temperatures. The highest temperature (max) is displayed by depressing the lower button. The lowest temperature (min) is then displayed for three seconds immediately after the lower button is released. The max/min memory is "cleared" to the current temperature by holding the lower button in and momentarily pushing the upper button. The max/min temperatures are retained in the memory even if power is removed from the TD-GL.

Operation

1. The TD-GL continuously displays the GL controls collector sensor temperature.
2. To display storage sensor temperature, press and hold the upper button.
3. To display the highest (max) temperature reached by the collector sensor since the last "clear," press and hold the lower button.
4. To display the lowest (min) temperature reached by the collector sensor since the last "clear," press the lower button and then release. The minimum temperature will be displayed for approximately three seconds. The display will then automatically revert to reading the current collector sensor temperature.
5. To "clear" the high/low (max/min) temperature memory, push in and hold the lower button and momentarily push upper button. Both maximum and minimum temperatures are set to the current collector sensor temperature.

1.2.4.4 GL-33 Solar Controls

The GL-33 is a differential temperature control for solar heating. The control output is wired to a circulator pump which is turned on when the collector sensor temperature is hotter than the storage sensor temperature. The control also provides an adjustable high limit function and selectable recirculate freeze protection. At Camp Pendleton, the GL-33 maximizes solar collection and minimizes the use of the backup system (gas system) to heat the pool.

Operation

The GL-33 test switch should be left in the "Auto" position, making the operation completely automatic with no operator intervention required. The "Power" indicator should always be on, the "Solar" #1 indicator will show when the system is collecting solar heat, and the "Freeze" #2 indicator will show when the system is recirculating to protect from freezing. To test the system, push the test switch to "On" and verify that the "Solar" #1 indicator is lit and that the pump connected to the control output is on. Move the switch to "Off" and verify that the "Solar" #1 indicator is off and that the pump is off.

In the test “ON” position, both the supply and return valves should drive to the open position and after it’s assigned delay period, the solar pump should come online. When placed in the test “OFF” position, the valves should close and the pump shut down immediately and simultaneously. The system should always be in the “AUTO” position when not being serviced by a technician.

1.2.4.5 Pump Control Panels

Class 87 pump control panels include a Class 14 magnetic starter with either a circuit breaker or a fusible disconnect switch, a “Start” button, and a “Hand-Stop-Auto” selector switch. These components are mounted in a NEMA 3R weather-resistant enclosure with a gasketed door that can be easily removed. This box is labeled “pump starter.”

1.2.5 BTU/Flow Meters

There are two types of BTU meters. One is an FP-93 (see Figure 15) and the other is a more simple one developed by Sandia Laboratories (see Figure 16). The components of the FP-93 are found below. Areas 14 and 53 tanks have precision BTU/flow meters (FP-93) to monitor the energy performance of the solar panel systems. The others have less-expensive BTU meters for monitoring energy performance. The FP-93 is a microprocessor-based instrument for monitoring energy production in an industrial environment. This programmable flow processor and remote terminal unit accurately calculates volume, mass, and heat flow rates for the water flowing through the solar panel system. Pressure and/or temperature compensation and a 8-point flow calibration curve enhance performance. All important flow-related variables are calculated by the FP-93 and may be displayed on the front panel along with their corresponding engineering units. Diagnostic routines constantly monitor the performance of the FP-93, and fault or alarm messages are automatically displayed upon detection. A copy of the FP-93 is included as an appendix.

A flow-pulse input, analog (4-20 mA) or RTD temperature input and an analog (4-20 mA) pressure input provide the FP-93 with the necessary signals. Two temperature inputs are standard for energy monitoring applications, one for the water entering the array and one for the water exiting. A 4-20 mA analog output monitors temperature, differential temperature, pressure, or any of the measured flow rates.

The FP-93’s backlit display allows the display to be read under all lighting conditions, from total darkness to bright sunlight.

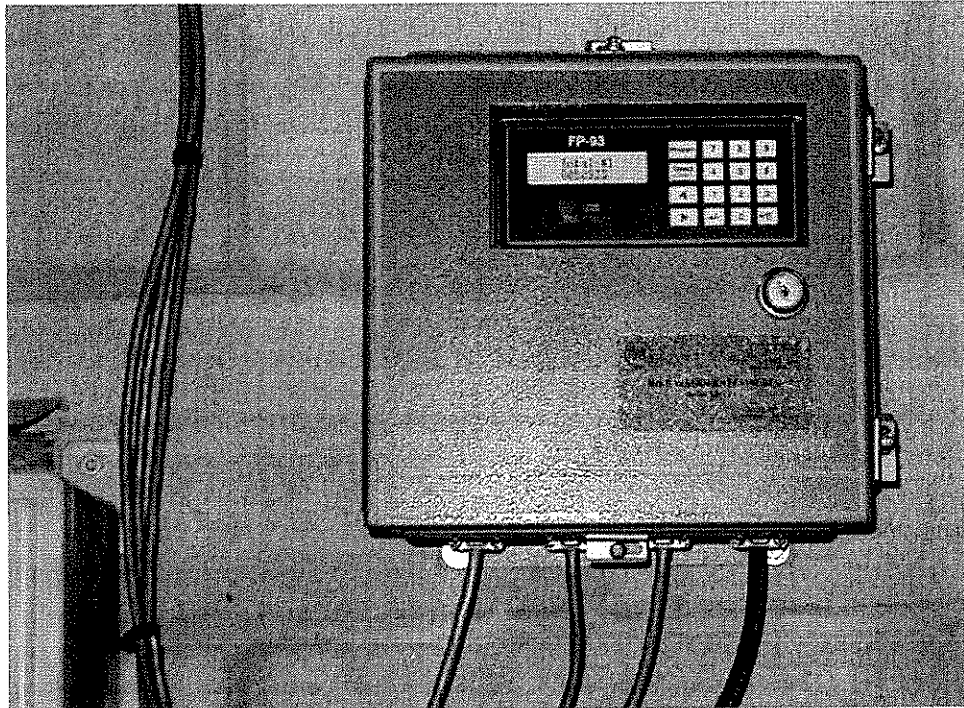


Figure 15. The FP-93 BTU Meter.

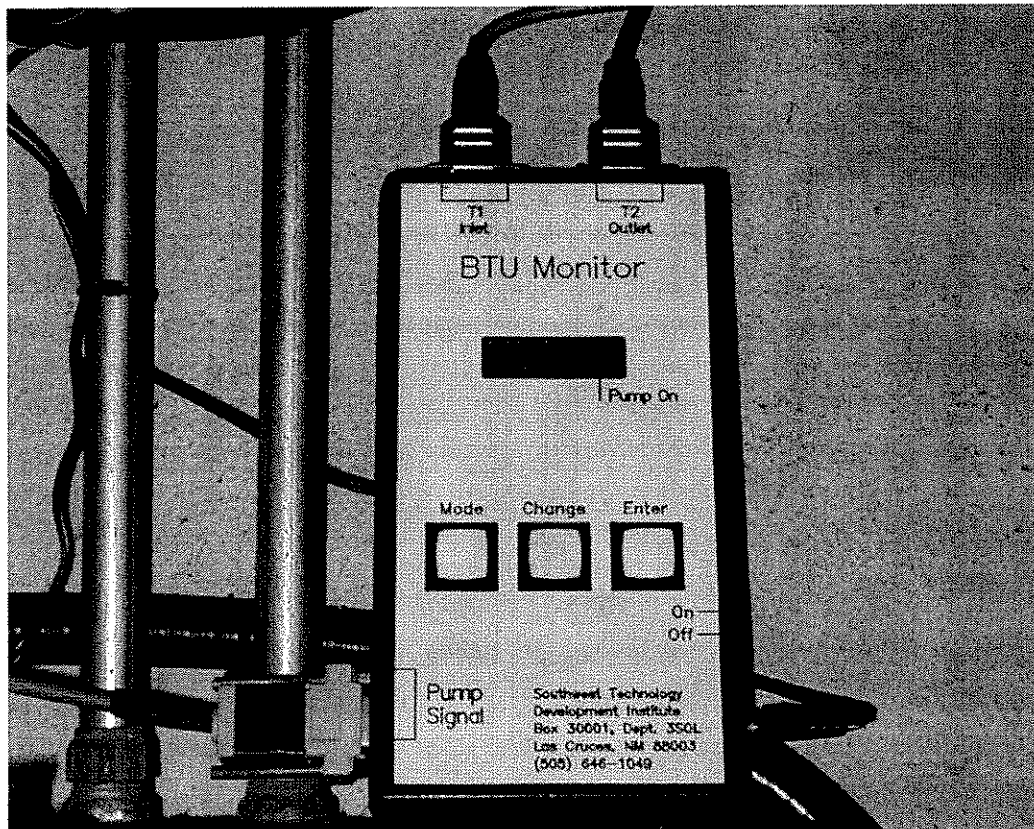


Figure 16. Sandia's BTU Meter.

1.2.5.1 Temperature Sensors for BTU Meter

The Temptran 4-20 mA Current Transmitter (see Figure 17) converts a resistance temperature detector's (RTD's) resistance signal into a current proportional to the RTD's temperature. The current changes according to the range marked on the Temptran: 4 mA at the lowest temperature of the range, rising to 20 mA at the top of the range. The leads that supply power also carry the current signal.

1.2.5.2 Orifice Plate

This system is mounted in line with the piping that carries water to the solar panel system. Two orifices on either side of the orifice plate (see Figure 18) are connected by small tubing to pressure sensors that are connected to a differential pressure sensor that is calibrated to produce a signal proportional to the flow rate. This signal is sent to the FP-93.

The FP-39 utilizes the pressure differential across an orifice plate to establish flow rate. This orifice plate is mounted between two 6 in. flanges in the solar return piping. It utilizes a square edge orifice in the center of the plate to create this delta-P. One-quarter-inch tubing piped into the "upstream" and "downstream" flanges carry this pressure difference to a transducer, which changes it into a 4-20 MA signal for utilization by the FP-93.

1.2.5.3 SANDIA'S BTU METER

The Sandia BTU meters do not measure the continuous flow of the solar loop directly, but use a flow rate that is input into the meter. This flow rate was determined by Sandia technicians using an ultrasonic flow meter and is fairly constant. This BTU meter uses two thermometers located on the inlet and outlet of the solar loop to measure the delta temperature (temp difference). Using this difference, the energy flow is calculated and tabulated. A manual for this meter is contained in an appendix.

1.3 THEORY OF OPERATION.

1.3.1 Control Logic.

A key to the successful operation of this type of solar hydraulic design (solar flow through a side-stream loop) is ensuring that the solar circulating pump *does not run* if the filter pump is not on-line. Previous circulating pump failures have resulted from the lack of flow that invariably occurs if the circulating pump is running without the net positive suction-head required, and supplied by the filter pump discharge. Therefore, each controller is equipped with a "filter pump ON" relay. This relay acts as the primary control: If the filter pump is not ON, there is no power

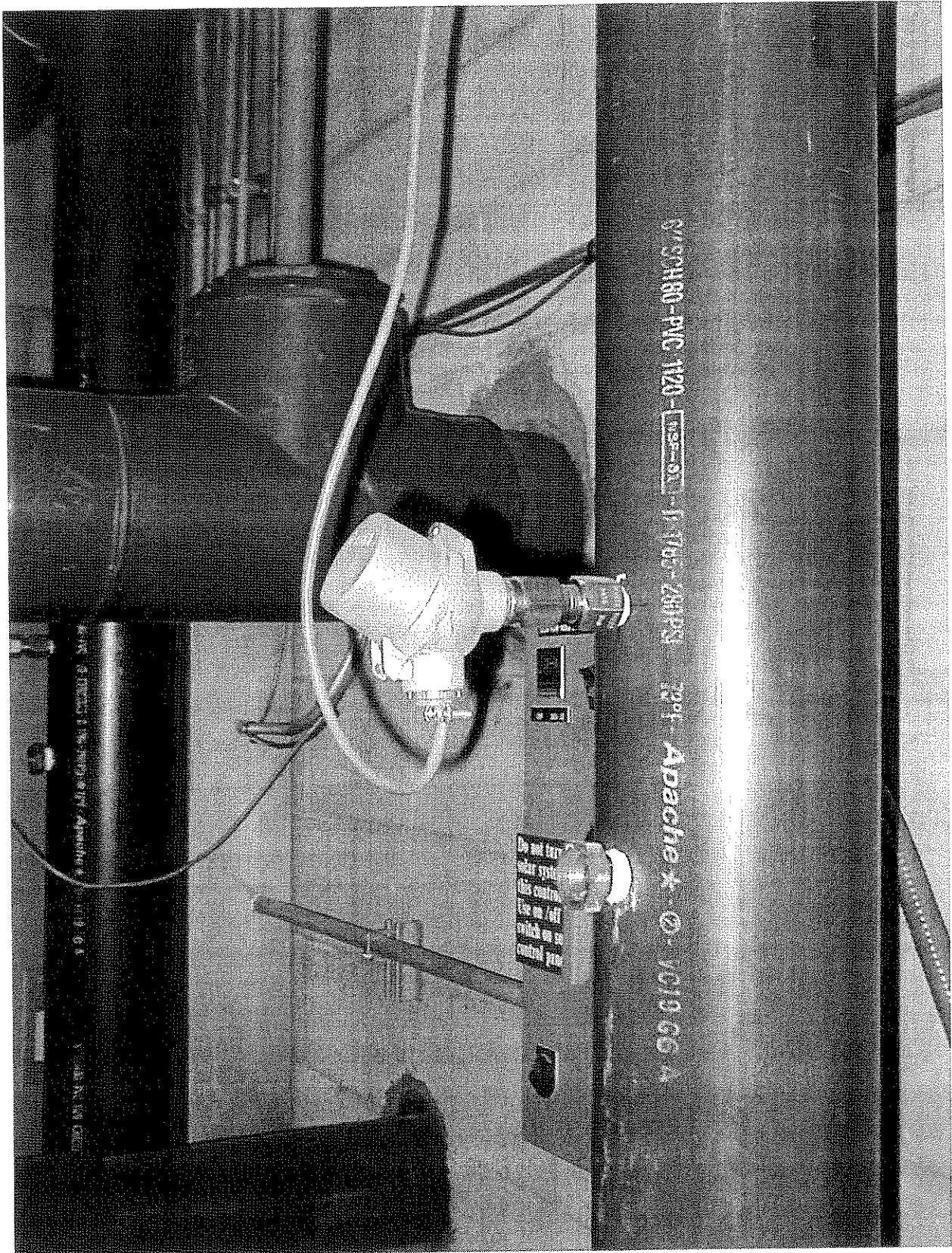


Figure 17. Temperature Sensors for FP-93.

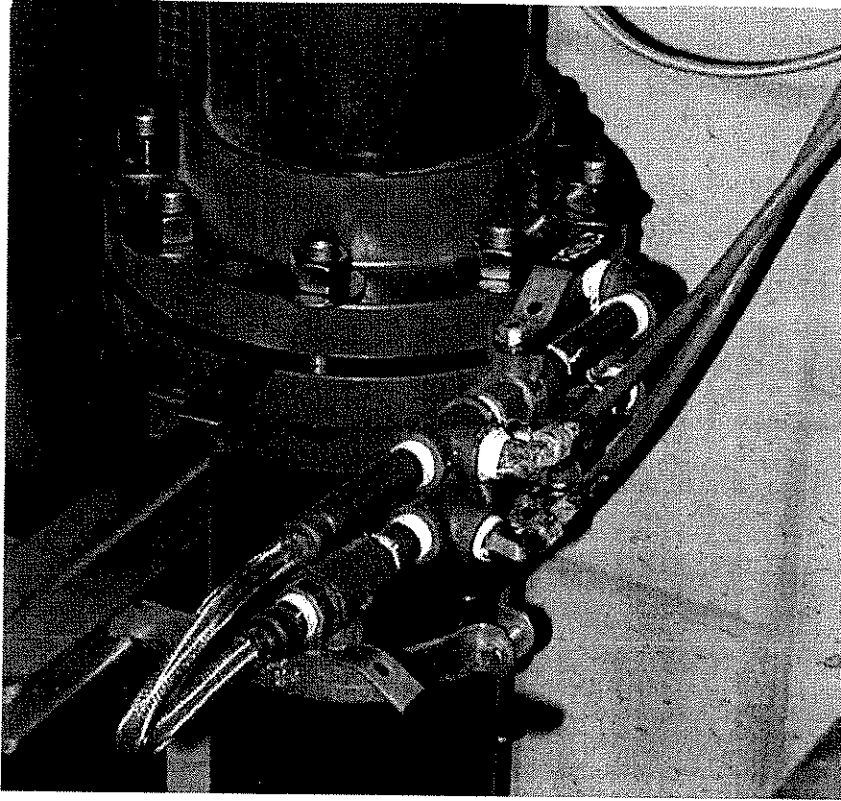


Figure 18. Orifice Plate for FP-93.

delivered to the differential thermostat, which in turn assures that the solar circulating pump cannot run and the valve actuators remain in the closed position.

With the filter pump ON, this relay is energized and power is routed to the differential thermostat. At this point there are several options:

- (1) If the solar array can heat the pool (i.e., the solar array is hotter than the pool) water temperature and the pool water temperature is less than the high temperature limit setting (around 83°F), the differential thermostat will energize both the circulating pump's delay relay and the valve actuator relay. Please note: there is always a 115-VAC power signal at the valve actuator relay. If the relay is not energized (e.g., the filter pump is OFF), the normally closed contacts provide power to the actuators to drive them to the CLOSED position. If the relay is energized, as in the above scenario, the power signal is switched to the normally closed contacts, driving the actuator motor to the OPEN position.
- (2) If the solar array cannot heat the pool (i.e., there is an inadequate temperature differential between the collectors and the pool water), the differential thermostat will

de-energize both the circulating pump time-delay relay and close the circulating loop valves.

- (3) If the solar array can heat the pool (i.e., the pool temperature is less than the high temperature setting and the sun is shining), but the pool water temperature has reached the high limit temperature setting (e.g., the pool water temperature reaches 83°F, the high temperature limit arbitrarily set by the pool's operators), the differential thermostat will again de-energize the circulating pump time delay relay and close the valves.
- (4) During extremely cold conditions, typically found in December and January during hours of darkness, it is possible for the collectors to suffer freeze damage. To avoid this, should the array sensor indicate near-freezing temperatures, the differential thermostat will energize the circulating pump time delay and open the valves. This will cause the pool water to recirculate through the array to prevent the water from being trapped there. This is a redundant safety system to prevent freezing. The array has a drain line that will drain the array whenever the solar circulation loop is shut down or when power fails.

As stated earlier, the solar circulating pump is energized by a time-delay control of the "hand" position (with exception as noted earlier) in that pump's motor starter circuitry. This time delay exists to ensure that the circulating pump is flooded before it starts.

All units are currently set with a three-minute delay or as indicated on the time delay relay in the control box (see Figure 19).

For quick reference, both the "filter pump ON" and "valve actuator relay" in each control panel have a small indicator light. When this light is lit, it indicates that relay is energized (e.g., filter pump ON relay lit means the filter pump is ON).

The solar panel system operates as the primary heating source for the pool. The fossil-fired system is the backup (see Figure 20). Although the two systems are not electrically interconnected, they are logically interrelated via their respective operational set points. If the set point of the fossil system is set to the maximum temperature desired by the pool, then it will tend to provide all of the heating required by the pool. The reason is that when the pool cools (typically overnight), this system will automatically come on (typically early in the morning) and heat the pool to its maximum temperature. When the sun is finally high enough in the sky for the solar system to begin work, it cannot operate because the pool is at its maximum temperature.

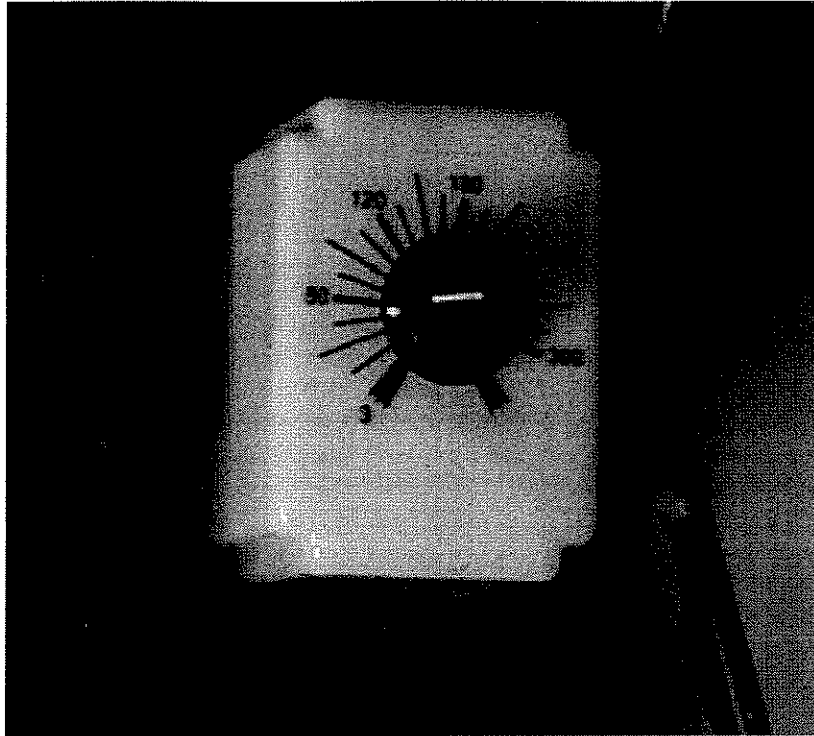


Figure 19. Time-Delay Relay in the Control Box (time units on this model are seconds).

The best strategy to obtain the most heat from the solar panel system is to set the *maximum temperature* of the fossil system to the *minimum* acceptable temperature of the pool. Correspondingly, the solar panel system maximum temperature setting should be set to *the maximum allowable temperature* of the pool. This will allow the solar panel system to do as much of the heating as possible and allow the fossil system to operate if, and only if, the solar panel system cannot provide adequate heating.

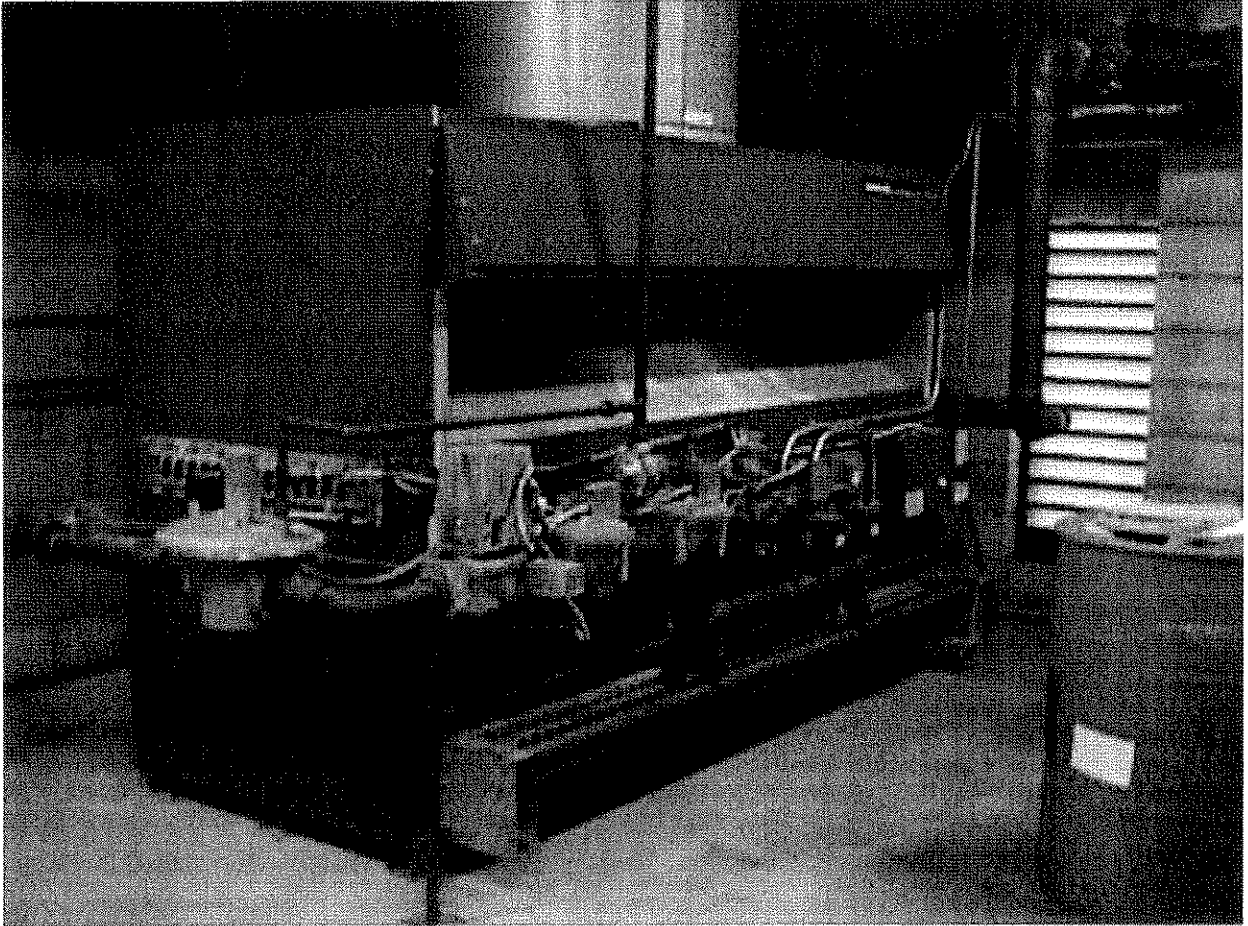


Figure 20. Fossil-fired Backup Pool Heater.

CHAPTER 2. PROCEDURES

System startup and shutdown under normal conditions are fully automatic. Upon startup of the pool's filter pump, a "filter pump relay" located on the control panel is energized. This provides power to the differential thermostat. At this point—depending upon current pool, ambient, and solar radiation conditions—the differential thermostat, also referred to as the controller, will either leave the solar system in the OFF mode or put the system into "solar collection" or ON mode. In the OFF mode, the solar pump is off and the supply and return valves are closed. If conditions dictate the system should be on, that is, the pool is in demand (requires heating) and the solar array is warmer than the pool water, the controller will drive both the supply and return valves open and, after a three minute delay, will energize the solar pump, causing flow through the array. The controller will continue in ON mode until either the pool temperature has reached a preset high limit setting (this is adjustable – see literature on differential thermostat), or there is no longer sufficient solar insolation available to positively impact the pool's temperature, or the pool filter pump is shut off, resulting in the deenergizing of the filter pump relay. The control logic is set up so that the solar system will not operate if the filter pump is off.

IMPORTANT: Any abnormal startup, that is, opening of the valves and/or running of the solar pump with the filter pump off, can lead to serious pump damage and possible failure. A manual startup of the solar system, or any individual components therein, should *only* be attempted by a qualified technician.

When backwashing the filters, it is possible for the filter pump interlock to be "on." That is, the filter pump is running, however, there is no flow in the filter piping except as occurs for backwashing. This is a dangerous situation in which the solar system can turn "on" the solar pump. Signs have been conspicuously located advising the site operators to turn "off," via the toggle switch at the side of the control box, the solar system prior to backwashing. The system is to be turned back on only after the establishment of flow in the filter system piping after completion of backwashing procedure.

It is possible that an emergency will arise that will dictate that the pool attendants, water quality technicians, or maintenance personnel respond prior to the arrival of the site's designated service technician. There are two general categories of problems that can arise: hydronic and electrical.

Emergency Shutdown. Should a major water leak or other mechanical or electrical failure occur, the immediate first response is to turn off the toggle switch at the side of the controller. Should the problem not be resolved, i.e., an electrical problem in the control box, but “upstream” of the toggle switch, go to the adjacent electrical control panel and open the breaker for the solar controller. Immediately afterwards call the O&M contractor to respond to the service call.

Small leaks, such as a drip at the array or an excessive amount of leaking at the pump packing, should be brought to the attention of the solar service technician, but if possible, the solar panel system should not be shut down.

The collectors (sometimes referred to as the panels or absorbers) utilized in the solar arrays, with the exception of Area 14 pool, are of metal construction. Because of this, they are susceptible to etching and ultimate failure when exposed to strong chemical solutions, that is, a flow that is either too acidic or basic, or a strong oxidizer (Chlorine) solution. Of course, these possible conditions will be damaging to other systems components, including the heat exchanger in the gas boiler. Therefore, in the event of either a failure of the automatic chemical treatment equipment or the need to shock the pool with a strong sanitizing solution, *the solar system should be turned off (using the toggle switch on the side of the control box) until the equipment is repaired or the shock treatment has had an opportunity to dilute.* As discussed in other sections, this switch will turn off the solar pump and isolate the array from possible harmful exposure by closing the supply and return valves.

CHAPTER 3. ROUTINE MAINTENANCE REQUIREMENTS

Solar thermal systems are, in essence, electromechanical in nature with a solar component. As such, the requirements for both periodic inspection and preventative maintenance are comparable to those of other hydronic systems with pumping and control inputs. It should be noted that an undetected calibration problem in one of the sensors can result not only in the loss of energy savings but additionally, and quite easily, increase energy usage.

IMPORTANT NOTE FOR POOL EQUIPMENT OPERATORS: The solar system must be shut down during backwashing cycles. Although the filter pump ON relay is energized (the filter pump is on), there is *no flow* in the pool filter piping beyond the filter banks (see Figure 21). With no flow at this location, solar circulating pump damage is inevitable. See Figures 22 and 23 for a closer look at the pool filter controls and warning signs.

3.1 SOLAR CIRCULATING PUMPS AND ASSOCIATED PIPING.

The pump motor should be examined to detect excessively hot bearings. Vibrations indicate either a bearing failure in the motor and/or a cavitation or balance problem in the wet end.

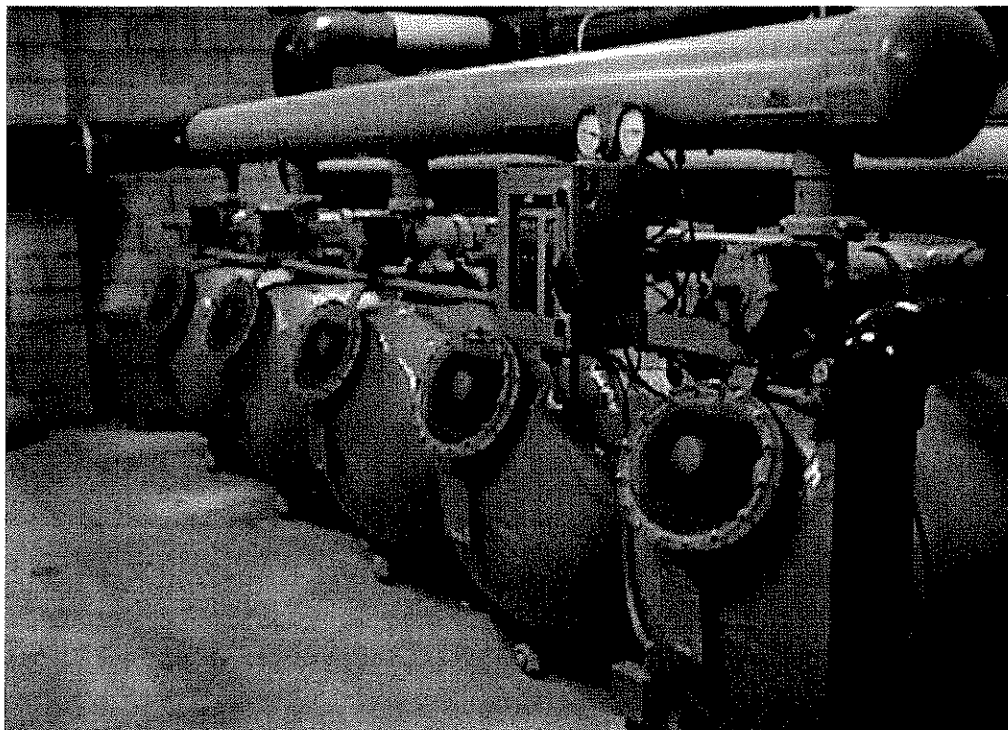


Figure 21. Pool Filters.

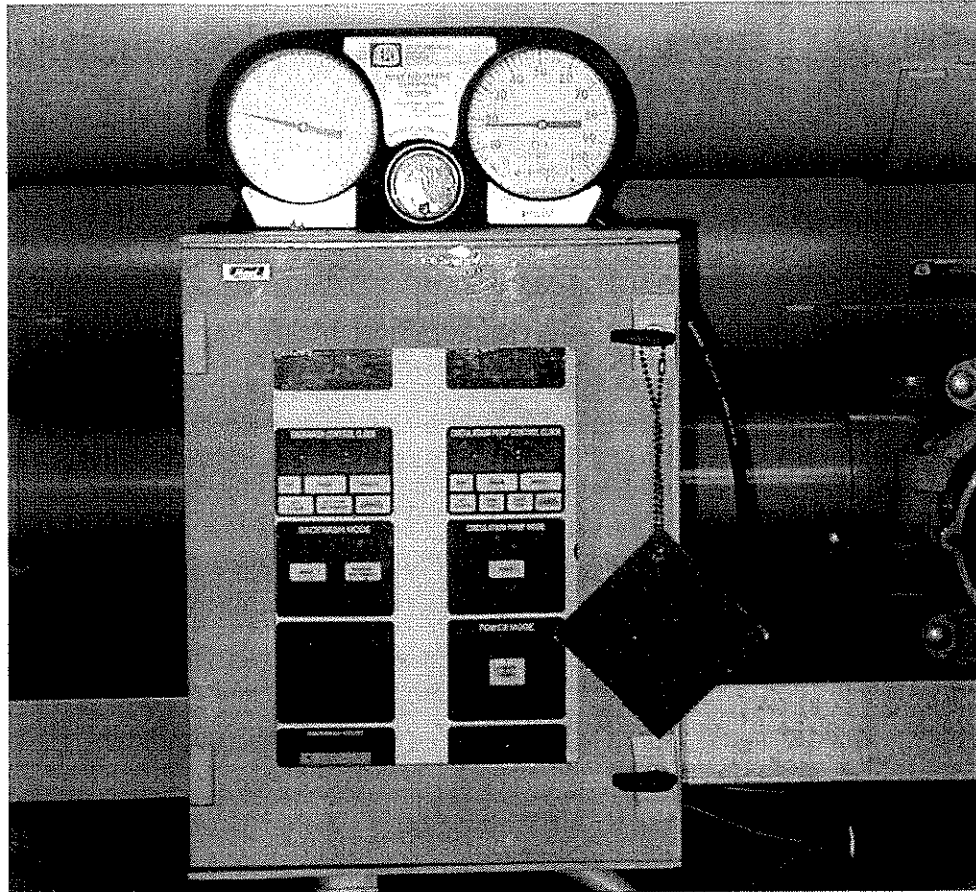


Figure 22. Pool Filter Controls.

Excessive noise may indicate a starved pump suction; look for an obstruction upstream, possibly an inoperative butterfly valve. The pump suction and discharge pressures should be noted; a significant change in either indicates the need to shut down and inspect for the cause. All pumps are equipped with a pressure gauge and the ability to read both suction and discharge pressures with the same gauge. Leaking seals can either be replaced with new mechanical seals or addressed by the installation of a conventional shaft packing.

The pumps have sealed bearings. The flanges at the newly installed flex-connections and valves should be kept leak-proof. Any pipe vibrations may indicate either a pump problem or a pipe support problem. The proper operation of the butterfly valves and their actuators is critical to system performance. Manually cycle the system “off,” then “on” to ensure that actuators are operating and that they are changing the valve position. If they are not operating properly, check for correct signal from the controller and verify that shaft cam stops and limit switches are engaging correctly.

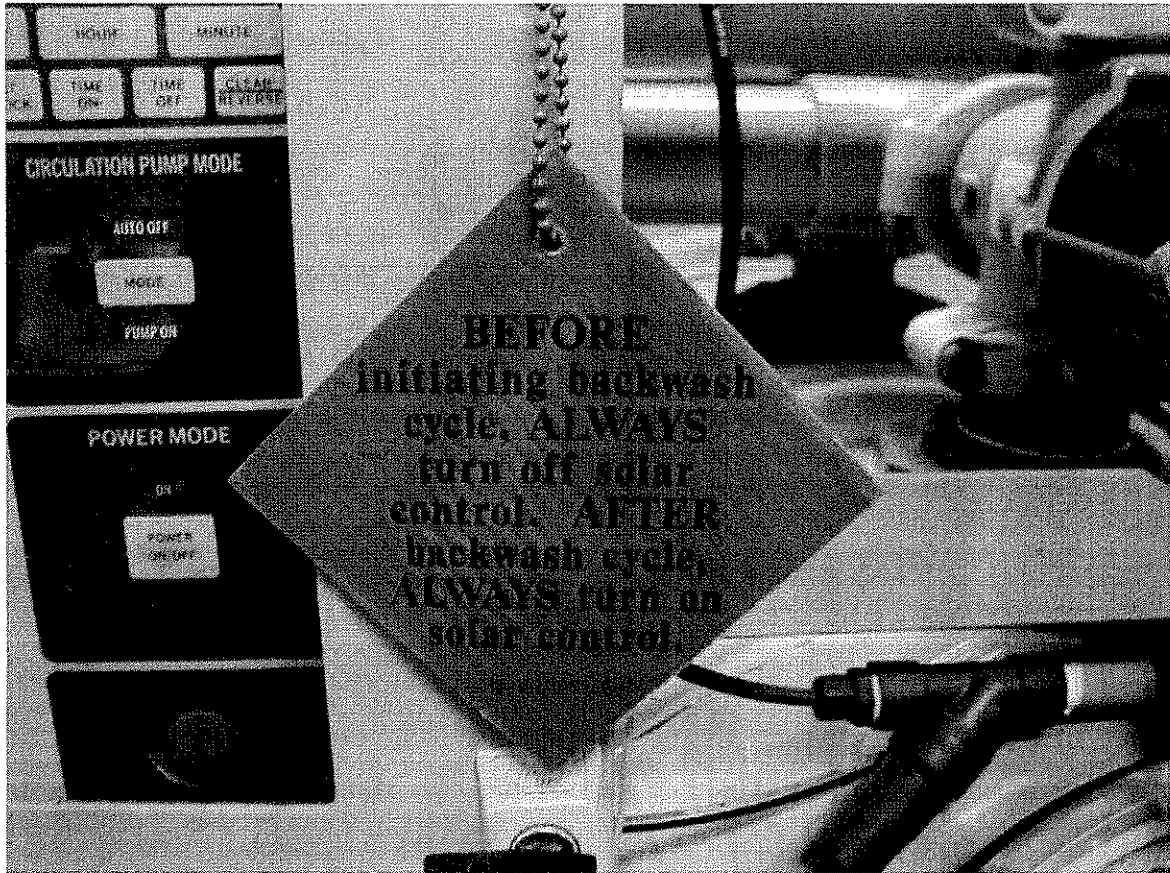


Figure 23. Pool Filter Warning Signs.

3.1.1 Electric Motor-Driven Pumps

Warning: Make certain that the unit is disconnected from the power source before attempting to service or remove any component.

Note: Always flush pump thoroughly after use or if unit is not going to be used for any prolonged length of time to prevent crystallization and/or damage to seal and pump.

1. Pump should be drained when subjected to freezing temperatures. A drain plug is provided on the pump casing.
2. Clean the suction line strainer at regular intervals.
3. Properly selected and installed electric motors are capable of operating for years with minimal maintenance. Periodically clean dirt accumulations from open-type motors,

especially in and around vent openings, preferably by vacuuming (avoids imbedding dirt in windings).

4. Periodically check to see if electrical connections are tight.
5. Pump should be checked regularly for proper operation. If anything has changed since unit was new, the unit should be removed and repaired or replaced. Improper repair and/or assembly can cause an electrical shock hazard, so only trained personnel should attempt to repair this unit.

3.2 SOLAR ARRAYS.

The age and construction of the original collector couplings may result in leaking unions and the requirement to replace them. Those devices mentioned above as replacements have a proven track record for durability and reliability.

The air vents may periodically leak water. This is usually the result of flooding the float chamber. A short-term solution is to tighten the vent cap on the schraeder valve. The appropriate repair is to drain the float chamber and very slowly refill by utilizing the vent hole in the cap.

The vacuum breakers are generally quite reliable and if operated under adequate pressure will not leak, with the exception of some "spitting" upon system startup. If they begin to leak continuously, replacement is appropriate.

The piping hangers are, in most instances, those originally installed. The array should be visually inspected to ensure that hangers have not come loose over time, forcing the pipe to support itself, which will result in piping failures.

The age of the racks indicates that a periodic visual inspection of securing details is appropriate.

3.3 THE SOLAR CONTROL PANEL.

The differential thermostat has two adjustable potentiometers. The "on" differential is adjustable from 8°F through 20°F. All units are currently set at 8°F. The "off" differential is factory set at 3°F. It is not likely that this should require changing. The "on" differential is the high temperature limit. There is a "On-Auto-Off" switch behind the front cover of the controller. The system can be manually cycled by manipulating this switch.

The solar pump time-delay relay is currently set at three minutes. Upon observation, it may be deemed appropriate to extend this delay. The timer has a five-minute delay capability. The delay period should not be set below three minutes. (See notations on solar pump time delay in “Control Logic,” above.)

The other two relays – filter pump ON and valve actuator – can be visually inspected and by cycling the differential thermostat “off,” then “on.”

As discussed in Section 1.3.1, freeze protection is currently provided by recirculation through the array.

The differential thermostat incorporates a digital readout located on its cover plate. This readout can provide the operators with:

- the current array sensor temperature,
- the current pool water temperature, and
- the previous high and low temperatures.

A quick glance at this readout will indicate which mode the controller is in and the appropriate state for the actuators and pump.

A toggle switch is provided on the side of the controller box that can be used to easily shut down the system if needed. Don’t forget to turn it back on at an appropriate time so the solar panel system can operate.

A Special Note: There have been collector failures that are possibly the result of chemical attack. Should it be necessary to manually add chemicals to any of the pools, it should be considered standard operating procedure to shut down the solar system prior to treatment. The filter system should be allowed to circulate for a minimum of 15 minutes prior to startup of the solar equipment. The best way to shutdown the solar system is to use the toggle switch on the side of the control box. Never shut down the solar pump controller, except in an emergency involving the solar pump motor (i.e., fire).

3.3.1 Vacuum Relief Valves.

These valves need no maintenance but should be replaced if they begin to leak.

3.3.2 Time Delay Relays.

These devices need no maintenance and should have a long life. If they fail, they should be replaced.

3.3.3 Pumps.

Note: The pump disconnects are used to isolate the pumps for servicing. **They should not be used to turn off the solar panel system.**

3.4 BTU METERS.

The BTU meters should be read periodically to measure and record energy performance. They should require no maintenance. If problems arise, the solar technician should be contacted.

3.4.1 Thermocouples.

These devices require no maintenance, but should be replaced if they fail.

3.5 REPLACEMENT PARTS.

The appendices have specification sheets for the components installed.

CHAPTER 4. TROUBLESHOOTING

4.1 TROUBLESHOOTING ELECTRIC MOTOR-DRIVEN PUMPS

Symptom	Probable Cause(s)	Corrective Action
Motor will not start or run	<ol style="list-style-type: none"> 1. Improperly wired 2. Blown fuse or open circuit breaker 3. Loose or broken wiring 4. Stone or foreign object lodged in impeller 5. Motor shorted out 6. Thermal overload has opened circuit 	<ol style="list-style-type: none"> 1. Check wiring diagram on motor 2. Replace fuse or close circuit breaker after reason for overload has been determined and corrected 3. Tighten connections, replace broken wiring 4. Disassemble pump and remove foreign object 5. Replace 6. Allow unit to cool. Restart after reason for overload has been determined.
Motor runs slowly; motor will not get up to speed	<ol style="list-style-type: none"> 1. Motor wired improperly 2. Capacitor burned out (single-phase units only) 3. One phase wiring burned out 	<ol style="list-style-type: none"> 1. Check and recheck wiring diagram on motor as noted per wiring diagram. Make internal wiring changes in wiring compartment 2. Replace capacitor
Pump will not prime	<ol style="list-style-type: none"> 1. No priming water in casing 2. Seal is leaking 3. Leak in suction line 4. Discharge line is closed and priming air has nowhere to go 5. Suction line (or valve) is closed 6. Pump is worn 	<ol style="list-style-type: none"> 1. Fill pump casing 2. Replace 3. Use thread sealant on piping, tighten, repair or replace 4. Open 5. Open 6. Replace worn parts
Little or no discharge	<ol style="list-style-type: none"> 1. Casing not filled with water 2. Total head too high 3. Suction head too high 4. Impeller plugged 5. Rotation incorrect 6. Hole or air leak in suction line 	<ol style="list-style-type: none"> 1. Fill pump casing with liquid 2. Shorten suction lift and/or discharge head 3. Lower suction head, install foot valve and prime 4. Disassemble pump and clean impeller 5. Correct (see wiring diagram in product sheet) 6. Repair or replace suction line

Symptom	Probable Cause(s)	Corrective Action
Little or no discharge (Continued)	7. Foot valve was too small 8. Impeller damaged 9. Foot valve or suction line not submerged deep enough in water 10. Suction piping too small 11. Discharge piping too small 12. Motor wired incorrectly 13. Casing gasket leaking 14. Suction or discharge line valve closed 15. Single-phase, new installation. Motor wired for 230V, etc. but supply is 115V, etc. 16. Seal is leaking	7. Match foot valve to piping or install one size larger foot valve 8. Replace 9. Submerge lower in water 10. Increase to pump inlet size or one size larger 11. Match to discharge outlet size on pump 12. Check wiring diagram 13. Replace 14. Open 15. Check voltage of incoming power supply. Rewire as necessary. 16. Replace (see product sheet)
Loss of suction	1. Air leak in suction line 2. Suction lift too high 3. Clogged foot valve or strainer	1. Use thread sealant on piping, tighten, repair or replace 2. Lower suction lift, install foot valve and prime 3. Clean
Pump vibrates and/or makes excessive noise	1. Mounting plate or foundation not rigid enough 2. Foreign material in pump 3. Impeller damaged 4. Worn motor bearings 5. Suction lift too high 6. Cavitation present	1. Reinforce 2. Disassemble pump and clean 3. Replace 4. Replace 5. Decrease suction lift 6. Check suction line for proper size and be sure valve is open. Remove excessive loops in suction line.
Pump leaks at shaft	1. Damaged or worn seal 2. Corrosion due to character or liquid pumped 3. Abrasive material in liquid causing an accumulation around the rotating assembly which results in faces opening up and allowing grit between them 4. Liquid not compatible with seal 5. Temperature too high	1. Replace (see product sheet) 2. Discontinue pumping liquid and consult factory 3. Pump not designed for abrasives. Discontinue use. 4. Consult factory. Operational seal may be available. 5. Lower liquid temperature below temperature rating of pump (see product sheet)

Symptom	Probable Cause(s)	Corrective Action
Pinholes in the casting, liquid drips around seal area	Cavitation caused by insufficient inlet pressure or suction head	Increase inlet pressure by adding a higher level of fluid to source, increasing inlet pressure, or remove piping restrictions (valves, loops, etc.) in suction line

4.2 TROUBLESHOOTING THE FAILSAFE VALVES

See previous section on the valves that describe their operation and status lights.

4.3 TROUBLESHOOTING TIME DELAY RELAYS

Should relay fail to operate, check all connections to relay and control circuits, verify that proper voltage connections are made, and check all fuses. For OFF delay relays, be sure that control switch is connected to pins 5 and 6 of the socket.

4.4 TROUBLESHOOTING TEMPERATURE DISPLAY FOR GL CONTROLS

1. For “no display” condition, check that power is connected to the GL control and that the GL control is operating properly. Next, check the wiring connection between the TD-GL and the GL control. Lastly, turn power off, wait one minute, and then reapply power. If there still is a problem, the TD-GL will have to be returned for repair.
2. For “partial displays” or general “erratic” operation: turn power off, wait one minute, and then reapply power. If there is still a problem, the TD-GL will have to be repaired or replaced.
3. For temperature displays that “bounce” between several different values: check that the sensor lines are not near other electrical cabling, and use shielded sensor wire if required.
4. For “erroneous” readings, check that the sensors are making good thermal contact with whatever is being measured. If the sensor is in a wet (constantly condensing humidity), moisture may, over time, enter the sensor body and result in errors. If this is the case, replace the sensor.

As a last resort, unwire the sensor from the GL control, measure the resistance with an ohmmeter and look up the corresponding temperature on an IE “resistance vs. temperature” chart (see

product sheet). This will allow you to determine whether the sensor or the TD-GL is causing the error. If it is the TD-GL, repair or replace the unit.

Caution: Disconnect power before working on electrical equipment to avoid electrical shock.

In many applications, the magnetic control can be expected to be trouble-free during the entire operating life of the pump. Routine inspection and maintenance as follows will help to ensure this.

1. Periodically clean the inside of the enclosure by blowing out dust, etc., which may have accumulated.
2. Periodically examine the contacts – cleaning is not required since the contact material is a special preoxidized silver cadmium oxide alloy. Replacement is required only when the contact material is almost worn down to the backing. Parts kits which contain a complete pole, stationary and moveable contacts and a contact spring, are available. Always replace all silver and the contact spring on a given pole. This ensures proper contact mating to provide maximum life.
3. Check magnet poles for foreign deposits and if present, carefully clean pole faces with solvent.
4. Check all screws for tightness.
5. Depress test-trip button on overload relay and then reset overload relay. This ensures the relay's ability to open the control circuit if necessary.